SIR WALTER KENT.

MEMBERS of the Institution will have learnt with deep regret of the death of Sir Walter Kent on November 11, 1938. Those who knew him, and who knew the part he played in the development of the Institution, will not need to be told that the Institution has lost not only a distinguished member but a leader and a friend. Sir Walter was President of the Institution from October, 1933 to October, 1935, a period marked by great expansion in the number of local sections established. He set himself to the task of seeing that this expansion was pushed forward with the utmost energy, and travelled all over the country in pursuit of that aim. During his term as President, the Western, Southern, Leicester, Edinburgh, and Preston Sections were formed, and a Graduate Section was established at London.

His interest in the work of the Institution of which he was the head was such that he not only presided at every meeting of the Council, but attended nearly every meeting of the Finance and Development Committee. He became Chairman of that committee at the conclusion of his period of office as President, and only relinquished the chairmanship last year when ill-health began to interfere with his many activities. But up to the last his interest in the Institution was maintained, and less than a week before his death he was in active correspondence with Institution headquarters.

The Institution is fortunate to possess an excellent copy done by Mr. Kemp Tebby, of the portrait in oils of Sir Walter by George Harcourt, R.A., one of the leading portrait painters of to-day. The painting conveys a very faithful impression of that genial personality which was so marked a characteristic of one whose courtliness and charm were reminiscent of a by-gone period associated with a distinction of manner which no longer prevails.

On news of Sir Walter's death becoming known, Lord Nuffield (President), Lord Sempill (Deputy-President), Mr. James G. Young (Chairman of Council), and Mr. R. Hazleton (General Secretary) joined in sending to Lady Kent and family the condolences of the Institution. Wreaths were sent by the Council of the Institution and by the President, committee, and members of the Luton, Bedford, and District Section.

At the memorial service in Luton Parish Church on November 15, attended by over one thousand persons, a large number of members of the Institution were present, including Mr. R. W. Bedford (Works Manager, Messrs. Geo. Kent, Ltd., past-Member of Council), Mr. R. Broomhead (Member of Council), Mr. F. Siddall (past-Member of Council), and many others. At Stanmore, where the burial took place later the same day, the General Secretary represented Lord Lord Nuffield, and the Council and members from Luton were again present in strength.

Although he lived to the ripe age of eighty, a zest for life and a remarkable freshness of mind marked his outlook to the end and made it a pleasure to share his companionship.

The Institution owes much to Sir Walter Kent. At an important stage of its development his leadership was a factor of great value. If ever the history of its first two decades comes to be written, Sir Walter's work will ensure him a high place among that notable band of pioneers who have been the founders and builders of the Institution.

THE PRINCIPLES OF ORGANISATION WITH SPECIAL REFERENCE TO PRODUCTION.

Paper presented to the Institution, Leicester, Sheffield, and Preston Sections, and Loughborough College Student Centre, by L. Urwick, O.B.E., M.C., M.A.

THE subject of my lecture to you to-night is "The principles of organisation with special reference to production." It is important to recognise that the word "organisation" has two aspects—a static or structural aspect and a dynamic or operating aspect. When you have designed a motor car, you have then got to build it. When you have built it, you have to maintain it and drive it. So with human organisation. There is the static or structural part, which is dependent on correct design, and there is the dynamic part which consists of making the design work.

This dynamic aspect of organisation again falls into two parts. There is the work of filling the positions required by the plan, or building the motor car. When they are filled, there is the task of securing that the individuals thus appointed work harmoniously together from day to day, or maintaining and driving the motor car. We may call these two tasks staffing and operating. They call for sound practical sense and considerable experience. They occupy an overwhelming proportion of the working day of most successful administrators.

For this reason practical administrators often fail to give sufficient weight to the structural aspect of the subject, or even to recognise its existence at all. Time after time it is said that "A" or "B" or "C" "is a great organiser." What is meant is that "A" or "B" or "C" has exceptional qualities of personality or drive which enable him to keep a group working together successfully. At the same time his actual appreciation of organisation in the structural sense may be negligible, and the distribution of duties and responsibilities among his subordinates may suggest Bedlam. But he gets his results, despite of and not because of, this weakness in structure, and with better structure he would get them more easily and at less cost.

What I have to say to you to-night is concerned exclusively with the structural aspect of organisation. In this sense and from this aspect, the term may be defined in the most general and elementary

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Loughborough, November 2: Sheffield, December 6; Preston, December 15, 1937; Leicester, March 17, 1938

way as " the process of determining all the activities necessary to a given purpose and dividing them into groups which may be allotted to individuals."

There are gradually emerging certain recognised principles which should govern this process of analysis of activities and their synthesis into groups, which in the vast majority of cases, should take priority over all personal questions. It is essential to the more effective conduct of our national industry that we should abandon attempts to strain structure into line with the idiosyncracies and interests of individuals in favour of adjusting the personalities available to the requirements of appropriate structure. In other words—" The game is greater than the players of the game, and the ship is more than the crew." No football team plays nine men behind the scrummage, merely because a couple of individual forwards fancy themselves as three-quarters.

I shall state the general principles so far evolved as briefly as possible. If I am a little categorical, you will no doubt enjoy pulling my leg later on.

In the first place, every organisation, other than the most elementary forms in which one man directs half a dozen others, has a division of activities in two senses. There is a division by vertical lines into kinds of activity. For instance, in industry there are groups concerned with accounting, with selling, with various processes of manufacturing, and so on. And there is a division by horizontal lines into levels of authority and responsibility. For instance, we have managing directors, departmental managers, foremen, and so on. From this it follows that every job in any organisation can only be described accurately and completely in terms of both these senses. Definition must include not only duties, the content of the job, but relationships, the form of its association with other jobs. In other words, you can only fix a position in an organisation, exactly as you can only fix a position on a map or chart, by relating it to both ordinates. The vertical division of activities involves certain concepts which may be stated briefly :

Duties are activities which the individual is required to perform by virtue of his membership of the organisation.

Responsibility is accountability for the performance of duties.

Power is the ability to get things done, that is to say, it is a function of knowledge, skill, or personal qualities.

Authority is the right to demand action of others. It may be (i) formal, i.e., conferred by the organisation ; (ii) technical, i.e., conferred by special knowledge or skill ; (iii) personal, i.e., conferred by seniority or popularity.

The general principles which I shall mention are eight. In the first place, all organisation must be the expression of a purpose, either explicit or implied. The fact that a department or section

exists and certain individuals therefore obtain employment, is no criterion of its utility. That can only be judged by relating its activities to the general purpose of the undertaking.

In the second place, authority—that is, formal authority—and responsiblity must be coterminous and coequal. It is futile to assign responsibilities to an individual without conferring upon him the authority necessary to discharge those responsibilities. To confer upon an individual authority without holding him responsible for the results involved is to allow him to escape from control.

From this it follows that the responsibility of higher authority for the acts of its subordinates is absolute. This holds good even if the superior is in London and his subordinate is in the Antipodes. The superior who quotes the actions of a subordinate as his excuse for a mistake condemns himself.

There must, too, be a clear line of formal authority running from the top to the bottom of the undertaking. Without such a clear line of authority there will be failure in co-ordination and confusion and uncertainty among subordinates. This is sometimes called "the scaler principle."

On the other hand, no superior can supervise effectively and directly the activities of more than five or six subordinates whose work interlocks. The higher the position in the organisation and the greater the responsibility of the subordinates, the smaller is the number which can be supervised directly. This principle is called "the span of control." I shall not go into the reasons for it in detail. But it has been proved valid by centuries of experience, and it is often overlooked in business organisation.

The sixth principle is specialisation—the work of every man in the organisation should be confined as far as possible to the performance of a single leading function. Function, of course, means a kind of work, and this principle is merely the application to mental labour of the sub-division and specialisation of task which is characteristic of manual labour under a machine economy.

This specialisation imposes an increased burden of co-ordination. The final object of all organisation is the smooth and effective co-ordination of effort. It is useless to assign duties to men and to trust to "the team spirit" or the "old school tie" to do the rest. If there is a need for co-ordination, then definite mechanisms must be provided to look after that need. Reverting to my analogy of the football team, the half-backs must be taught to work the scrummage and the three-quarters how to give and take a pass. "A good understanding" is invaluable in any organisation. But, men must be given something to understand.

Thus every position in every organisation should be laid down precisely in writing, including both the duties involved and relationships with other positions—the principle of definition.

Turning to the lateral grouping of activities, it will be found that in all organisation, this grouping takes place in accordance with one of three main principles. Under the unitary principle, the superior is responsible for all the activities, either of a group of persons, as in the case of the centurion in the Roman army, or which take place in a given area, as for instance in the case of a sales manager for Northern England, or which are related to a particular product, as when a manufacturing business is divided into certain departments making different products.

Under the serial principle, the superior is again responsible for all the activities within his span of authority. But the limits of the authority of each individual are determined by process, as for instance, in the case of a factory divided into foundry, forge, machine shop, sub-assemblies, main assembly, and so on. Alternatively, the limits are fixed in relation to a particular type of equipment, as in the case of a typewriting department or the artillery in an army. This latter form of organisation may not seem to accord with the serial principle. But it should be recognised that such groups of similar equipment are always set up to carry out similar processes in different production series or, in the case of the artillery, different destruction series.

Finally, there is the functional principle, where the responsibility of the superior is for all work of a particular kind within an organisation or department, as in the case of an accountant, chief engineer, or purchasing manager. The present tendency in industry is towards an increasing proportion of the functional principle, as contrasted with the unitary and serial principles.

The vertical grouping of authority and responsibility into levels has been less studied than forms of lateral grouping. The most important distinction is that between administration and management. Administration is concerned with the determination of policy, settling the compass of the organisation, and the final control of the executive. It is essentially deliberative in character. Management is concerned with giving effect to policy within the limits determined by administration. It is essentially executive in character. A board of directors should confine itself to administration. Being a committee which only exists intermittently, it cannot execute. Execution postulates continuous application. A more refined analysis shows seven distinct levels of activity. These are :

(1) *Criticism and review*, the function of the House of Commons in relation to government, or of the shareholders in a business.

(2) *Governing authority*, i.e., administration, the function of the Cabinet or of a board of directors.

(3) *Liaison between policy and operation*, the function of a Minister in relation to his department, and part of the function of a managing director.

(4) *Operating authority*, i.e., management, the function of the permanent head of a Government department, or of a managing director or general manager.

(5) *Supervision of operation*, the function of the various grades of officials or managers.

(6) *Operation*, the function of rank and file workers.

(7) *Jurisdiction*, the interpretation of the rules laid down by administration, represented by the Courts in Government, but in business usually combined with operating authority.

Supervision of operation divides up, of course, into many grades or sub-levels. The two main points to be distinguished in settling such sub-levels are the degree of supervision exercised by the superior, and the amount of responsibility for results left to the subordinate.

The interlocking of the lateral and vertical divisions of activities issue in four main types of relationship : (*a*) Line relations are those between a superior and the subordinates directly responsible to him ; they are usually formal ; (*b*) lateral relations are those between positions in different parts of an organisation where no direct authority is involved ; they are usually informal ; (*c*) functional relations are those between individuals, one of whom exercises authority by reason of special skill or knowledge in respect of a particular subject ; they often exist side by side with line relations, but they should be formalised as far as possible ; (*d*) staff relations are those between individuals, one or both of whom is acting on the authority and responsibility of his superior, this relationship is very little developed in industry, but signs of it may be found in such positions as " assistant to " or " secretary to " a managing director,

It is a common delusion that organisation in a particular enterprise must follow one of the principles suggested here to the exclusion of the others. Writers on business talk of "the staff and line form" of organisation or " the functional form " of organisation. This is nonsence. In every complex undertaking all the principles in the lateral and vertical grouping of duties and all the relationships which have been enumerated will probably be found at some point or other. The art of organisation consists in determining the correct principle to apply to each aspect of the activities of any enterprise, and to build up a structure in which the balance of principles and relationships is the most effective for the purpose of the enterprise, in such a way that the eight general principles are nowhere infringed. They are, of course, of universal application. The general outline of the principles of organisation suggested is shown in Fig. 1.

Turning now to the problem of organising the manufacturing or production activities of any business, our first task is to determine what are the main activities involved. Taking the production activities in their logical order, these are :—

(1) The general management of manufacturing—the directing

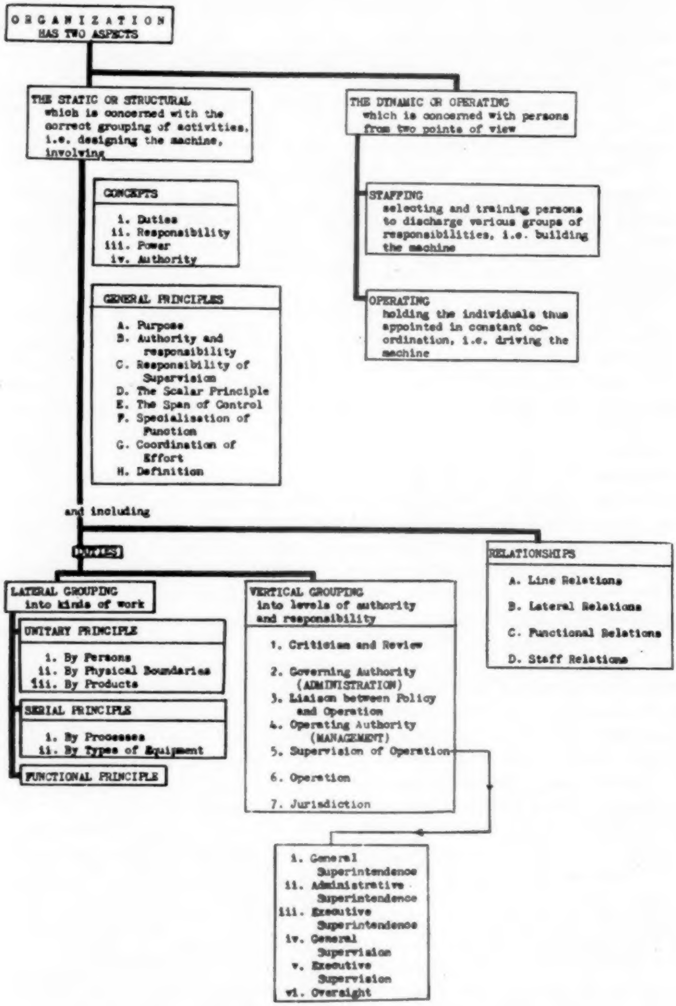

Fig. 1.—Outline of the Principles of Organization.

and co-ordinating activity.

(2) Determining what you are going to manufacture, which gives the activity of design. This often involves two or more separate stages : (*a*) Research on a laboratory scale ; (*b*) experiment on a semi-commercial scale. It may include fairly elaborate arrangements for testing the quality and particularly the durability of experimental products.

(3) Determining how you are going to manufacture it, which gives the general activity of methods research. This has two distinct sides : (*a*) That connected with materials, machines, and processes—technical research ; (*b*) that connected with labour, e.g., time-study department.

(4) Providing the buildings and equipment necessary to carry out the manufacturing methods decided upon. This leads to a number of separate activities, viz.: (*a*) Building ; (*b*) the specification of equipment, which follows on (2) and (3) ; (*c*) the buying of equipment, which is part of the function of purchasing.

(5) Maintaining buildings and equipment provided, including : (*a*) Repair and maintenance of equipment, which should always be kept distinct from the design, building, and erection of new equipment ; (*b*) the maintenance of buildings, etc., i.e., cleaning and painting ; (*c*) measures of security such as the maintenance of a fire brigade, insurance of buildings and equipment, etc. ; (*d*) process steam raising ; (*e*) heating steam raising or other methods of heating ; (*f*) air conditioning and ventilation ; (*g*) lighting.

(6) Providing the primary and secondary materials necessary for the manufacture of the product. This involves the activities of : (*a*) Buying materials ; (*b*) transporting materials inwards ; (*c*) receiving materials ; (*d*) testing materials.

(7) There follows the storing of materials until they are required for use.

(8) Providing and maintaining the necessary working force. This includes : (*a*) Selection of personnel ; (*b*) engagement of personnel ; (*c*) supervision of personnel ; (*d*) training of personnel including supervision ; (*e*) medical, dental, and optical services to personnel ; (*f*) canteens and other welfare arrangements ; (*g*) payment of personnel ; (*h*) time-keeping arrangements ; (*k*) transfer and promotion ; (*l*) retirement of personnel ; (*m*) overtime and short-time arrangements ; (*n*) negotiations with trade unions or other bodies representing the workers.

All these activities which have been listed are, as it were, precedent to the actual manufacturing processes. Assuming that the factory and the necessary equipment and services are set up, there remain :—

(9) The planning of manufacturing. Under this heading are included : (*a*) Arrangements for routing materials and products from process to process ; (*b*) issue of instructions to workers ; (*c*) rate-setting ; (*d*) following-up of orders in process.

(10) It follows from your plan that there is a further activity of transport, conveying materials or goods in process to the point at which they have to be worked upon.

(11) Only when all this preliminary work is accomplished can the actual manufacturing processes begin. These may be simple or extremely complex, according to the nature of the product.

(12) If the factory desires to maintain a high standard of quality this leads to the function of inspection.

(13) The finished product may have to be stored for a period, and this leads to a further storekeeping activity.

(14) When required by customers, the product must be packed and despatched.

(15) This gives rise to a further activity of transport.

(16) Finally, the manufacturing processes have to be costed, and any other statistics or control figures necessary must be provided—a clerical activity.

To summarise, there may be within the orbit of a modern factory's manufacturing arrangements, 16 major activities. These are general management, design, methods research, provision of buildings and equipment, maintenance of buildings and equipment, buying materials, storing materials, personnel, planning, internal transport, manufacturing, inspection, warehousing, packing and despatch, external transport, costing, and records. And these activities are all essential, irrespective of the size of the undertaking. They have to be undertaken some time by someone, even in the smallest factory. Let us consider in the first place which of these activities impinge on other functions in the organisation.

Production is one of the three major activities in any manufacturing business. In the old days it was sometimes thought to be the whole business. And in almost all cases which have come to my notice, whether in large or small businesses, there is a growing tendency to break down the activities of those reporting immediately to the managing director or principal executive into the three classic groups—production, distribution, and financial, the financial function including all figures and statistics, secretarial duties, and the general oversight of clerical activities wherever occurring—what is sometimes called in the U.S.A. the controller's function.

In circumstances where the financial or controller's function is fully recognised, and particularly where the controller has a competent clerical or office manager reporting to him the production manager will not have to worry himself unduly with costing and

clerical records. There will be clerks under the direct control of, that is, in a line relationship to, various manufacturing departmental managers. But, the costing and accounting systems will be laid down by the controller. And he will exercise a functional supervision over the clerical methods employed in the different sections of production, including the planning department. It will be his duty to see that the production manager obtains the figures and records he requires to do his job properly.

In the second place, the work of the design department may be considerably affected by the growing appreciation of the distinction between marketing and selling. Put briefly, marketing is concerned with what shall be sold, at what price, and in what quality, how it shall be packed, presented, and advertised, and through what channels it shall be distributed. Selling is concerned with the organisation and control of the personnel engaged in the securing of orders from the company's customers. Marketing looks at products and consumers. Selling looks at sales areas and customers who are, usually, distributors.

One of the reasons for segregating marketing is just this, that in the nature of things, the sub-division of marketing activities must be on a different principle to the sub-division of selling activities—the first by groups of products, and the second by areas.

Where a separate marketing department is organised, it may report direct to the principal executive, or through the executive in charge of distribution as a whole. In any event, such a department, if it exists, acts as a buffer and a link between production and selling, particularly in such questions as the organisation of a supply of new lines and their development on a commercial basis, the packaging of the company's products, and the determination of standards of quality.

If there is a marketing department, the design department will need to work very closely with it throughout all the processes in the development of a line. The marketing department is the authority as to what consumers need, and is responsible for seeing that the company's price list accords as closely as possible with its estimate of those requirements. That means, lateral relations and functional relations between the departments. There must be some machinery of co-ordination, possibly a marketing committee with sub-committees dealing with various product groups. Though I must confess I am not enamoured of committees in organisation. I prefer individuals. Possibly an assistant to the design manager, or to the marketing manager, or to both, may be made responsible that the necessary co-ordination between the activities of the two departments is maintained. An American example showing the development of the relationships between merchandising or marketing design is given in Fig. 2.

It is noteworthy that these two major activities which impinge most closely and most clearly on other functions of the organisation, occur at the extreme ends of the activities of the production function, if such activities are arranged in logical order.

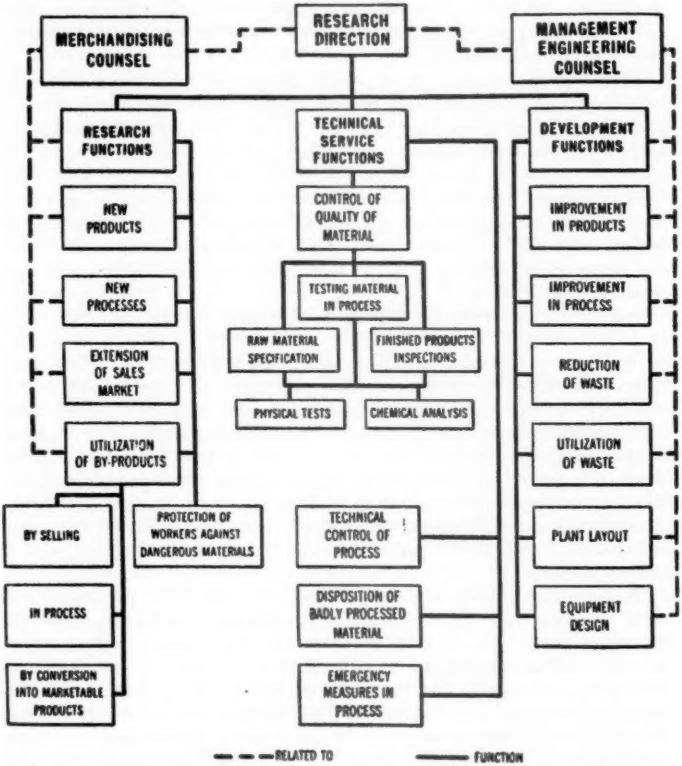

Fig. 2.—Research functions in relation to merchandizing and management engineering. (Copyright Bigelow, Kent, Willard & Co., Inc., Boston, 1930).

In addition to these two activities which *must* be associated functionally with other parts of the organisation, there are a number more which *may* be placed under executives charged with other major groups of functions, where this appears convenient and desirable.

First of all, warehousing of finished goods, packing and despatch, and external transport (Nos. 13, 14, and 15) may be regarded as part of the function of distribution, and placed under the general charge of a transport or warehouse manager, reporting to the distribution manager. The production manager's function will then end with the delivery of finished goods into warehouse. Which arrangement proves most convenient depends largely on the system of physical distribution. If distribution is largely through depots closely linked up with the central warehouse, on the one side, and the sales force on the other, the balance of advantage will probably lie in treating them as part of distribution.

If this is done, two points call for attention. The man with the best knowledge of methods of transport will be under the distribution manager. He should control inwards transport of material, as well as outwards transport of finished products. And he should also be given some functional authority over internal transport. The labour employed in warehousing, packing, and transport is of the factory type. If the control of personnel is specialised, as it should be, the distribution manager should be required to use the personnel manager's functional authority in dealing with this labour.

Turing to the other end of the scale of activities, there are businesses in which design and methods research (Nos. 2 and 3) are regarded as of such major importance as to call for the undivided attention of a major executive (development manager) reporting direct to the general manager. This, personally, I regard as undesirable, because it increases the general manager's span of control. But it still provides a logical and workable arrangement. Where this occurs, the production manager's duty is to arrange for the manufacture of products to a design and by methods laid down by the development manager.

Where, in such circumstances, the development manager is a skilled engineer, it may also appear convenient to place the provision and maintenance of buildings and equipment in his charge, subject to the proper exercise of the functions of the purchasing department in the routine of buying equipment, etc. With this arrangement it is clear that there must be close co-ordination between the maintenance and manufacturing sections and probably certain personnel in manufacturing departments under the "line" control of departmental managers, but with "functional" control exercised by the maintenance manager.

The buying and storing of materials are other activities which may or may not be placed under the general production manager. Broadly speaking, if the major emphasis in the buying process is on the investment in stocks of materials and the financing of that investment, the purchasing department may well come under the executive in charge of finance. If, on the other hand, the major

emphasis is on close planning to meet the needs of production, then purchasing should come under the direct control of production. If the buying of the enterprise is centralised, as it should be, then the purchasing department will be buying for other functions such as stationery, salesmen's motor cars, and so on. There must be arrangements for co-ordinating this work.

The storage of materials may be under the control of the purchasing manager, an arrangement which is logical and convenient. Alternatively, if production, as the party most immediately affected, is likely to keep a closer watch on stock levels and the availability of supplies to meet the manufacturing plan, storekeeping activities may be placed directly under production.

Personal management is again a function which may be organised independently of production. Logically, a personnel or labour manager should be responsible for the company's relations with all grades of its staff. And actually this arrangement is sometimes adopted, a personnel director reporting directly to the managing director. In practice, however, there is a quite natural tendency for the principal executive to concern himself closely with the managerial grades only and with the policy adopted in dealing with other grades. The detailed work of personnel management is left to the personnel manager.

Since the bulk of the employees concerned are usually in the manufacturing departments, it is most convenient that the personnel manager should be responsible directly to the general production manager. He should, however, exercise a functional supervision over the relations between groups of employees in other divisions such as salesmen, technicians, or clerical staff, and the company.

We have now dealt with nine further activities which may or may not be directly under production, depending on the general structure of the organisation, and the balance of convenience in each case. It is clear that they are closely associated with production, and that, wherever direct responsibility for the conduct of these activities is placed, arrangements for close co-ordination with manufacturing activities are essential. There remain the production activities par excellence which, in any circumstances, should be the direct responsibility of the manufacturing manager.

These fall into two broad groups. Planning, internal transport, inspection, and costs and records, are functional or service departments common to all manufacturing departments. Manufacturing itself includes those departments actually engaged in the process of making the company's products. Responsibility for these actual manufacturing units will almost always be divided either on the unitary principle by groups of products if manufacturing is centralised, or by area if there are a number of works in different places,

or on one of the two varieties of the serial principle. Typical examples of organisation in a small factory (200 to 400 employees) and in a large factory (3,000 employees) are given in Figs. 3 and 4.

What I have tried to do to-night is to give you, first, the principles of organisation, and secondly, a frame of reference to which you can relate the structure of any kind of production organisation which you may encounter.

This frame of reference indicates how responsibilities can be broken down and allotted to individuals without infringing any of the general principles of organisation, while providing for specialised supervision of all the activities essential to production. Broadly and diagrammatically, its shape is a figure composed of two triangles superimposed on each other. (Fig. 5).

The lower triangle is divided into two parts. The bottom half represents the actual manufacturing departments divided on the unitary or serial principles. The upper half represents the four functional activities servicing production as a whole: internal transport, internal planning, inspection, and cost and records or, as it is sometimes called, production control.

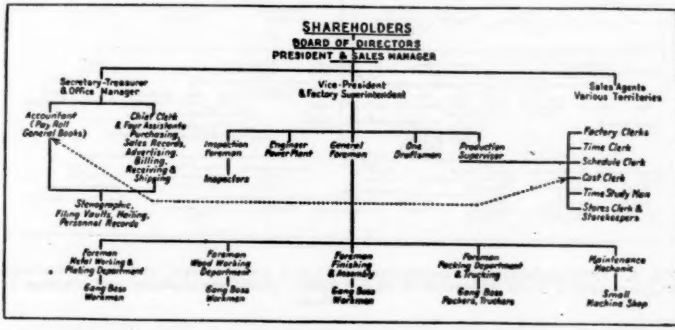

Fig. 3.—Typical General Organisati n Chart of a Small Factory with a Total Personnel of from 200 to 400, (Note Concentration of Functions as Compared with Fig. 5).

This group of activities is essentially the responsibility of the general works manager and, since he cannot (without exceeding his span of control) supervise four functional departments and at the same time a series of manufacturing departments, he will usually have a works manager or senior foreman in general charge of the manufacturing departments as such. The apex of the triangle is,

therefore, the general works manager. The functional departments included in this triangle service manufacturing only.

The upper triangle is also divided into two parts. The lower half represents the ten other activities essential to production. The upper half shows how these activities may be arranged in four major functional groups. These functional groups may, and frequently do, service other parts of the organisation in addition to manufacturing. For this reason, various modifications of the arrangement shown are possible, and not necessarily undesirable. Transport may be grouped under distribution, purchasing may be grouped under control,

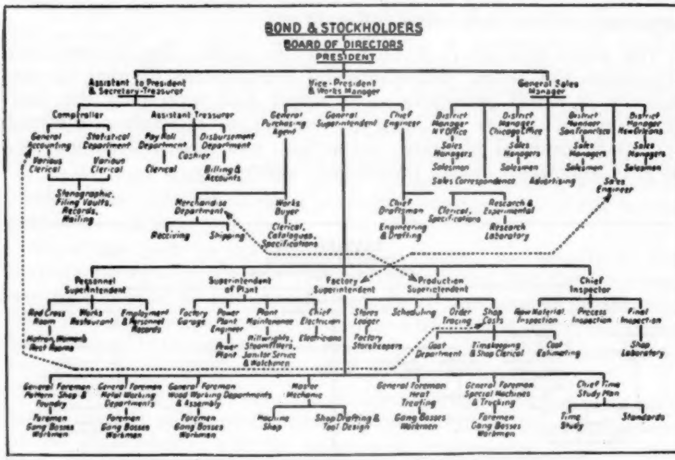

Fig. 4.—Typical General Organization Chart of a Large Metal and Wood-Working Factory with a Total Personnel of about 3,000. (Note multiplicity and division of functions.)

development may be placed directly under the principal executive (leaving only a maintenance department under production), personnel may be placed directly under the chief executive, and so on.

What suits one organisation will not suit another. But, whatever permutation and combination of activities is adopted, the logical and practical relation between these activities which I have tried to sketch to you, remains. They are all essentail features of the total process of production. And if they are placed under different individuals, and are not responsible to the principal production executive, mechanisms for co-ordinating them with the needs of

production must be provided. Where there are no " line " relationships, there must be effective " functional " relationships and, if the organisation is at all complex, " staff " relations as well.

I am afraid this has been a somewhat arid and theoretical address, but it has attempted to cover in a brief period a very wide and complex subject.

I would leave with you two thoughts. If the theory of organisation is dry, it is but the anatomical laboratory. Organisation in practice is as rich and varied and vivid as life itself. Without sound

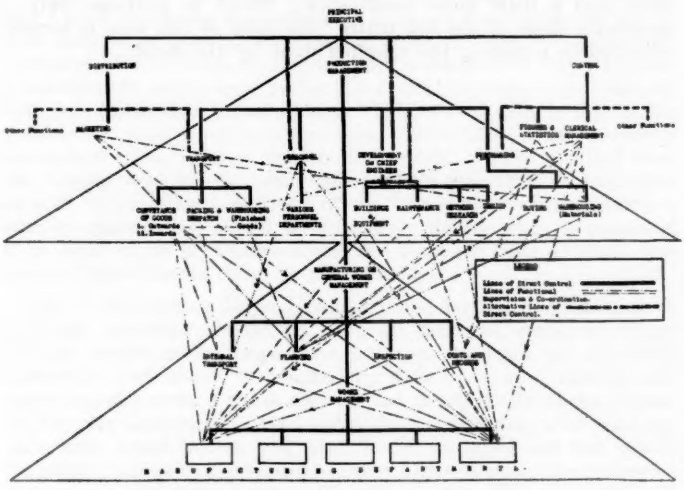

Fig. 5.—General outline of Production Organization.

organisation, the best of human material will fail to do itself full justice. With sound organisation, quite ordinary people can surpass themselves. The well-organised business is a place in which human beings work happily and honestly with each other for a common purpose. The ill-organised business is a place where personal politics are the major interest and where a taste for sycophancy, coupled with a distaste for accuracy, are the surest passports to advancement. Organisation principles are worth study because in the final analysis, they make people happier.

But principles are *not* rules. If you attempt to apply rigid rules to organisation, you will encounter the worst kind of trouble. They

are guides to thought, just as ethical principles are guides to action. They have to be interpreted and adjusted to the circumstances of the individual case. They cannot, however, be ignored with safety. The man who is unprincipled and opportunist in building an industrial organisation is quite as immoral as the man who is unprincipled and opportunist in personal conduct and, for the reasons given above, he is far more dangerous to the community. He may have the best of motives. He may be a kind husband, a generous father, and a benevolent employer. All the same, his business will be an uncomfortable place in which to work, and his employees will wish sooner rather than later that there was a little less benevolence and a little more intelligence. Which is, perhaps, only a particular facet of the old truth "the time of the wise is largely occupied in repairing the mischief done by the good."

Discussion, Leicester Section.

Mr. L. H. Leedham (Section President, in the chair): I would like to thank Major Urwick, on behalf of the Institution, for the trouble and time he must have put in for the preparation of a paper of this kind. It has been an inspiring and instructive lecture, and one in which all of us have taken a keen interest. I could not help but think how beneficial it would be if we all tried to analyse our own organisations by means of a chart such as has been suggested to-night. I have tried this experiment on a number of occasions and I have not found it at all easy. I do not think you will find it is so easy to prepare an organisation chart of your own particular company. Whilst some of the ideas and remarks that Major Urwick made to-night might seem rather theoretical to most of us, I cannot help but think that industry, as a whole, would greatly benefit by getting its house in order in this way. There must be an enormous amount of waste in most industrial concerns, due to the fact that the management has no clear conception of the duty and functions of each of its officers, and one of the first steps towards getting a simple organisation would be to clearly define what is expected from each of its members—from the manager right through the various departments down to the office boys.

I have been asking Major Urwick exactly how far the question of personal authority should go. We all know of instances where certain people in an organisation appear to have an all-round authority, and unless that authority falls on a very careful and experienced person, I think there is not much doubt about it that he is a very dangerous type of individual. If this man with personal authority, about whom you have heard to-night, has not sound judgment, it is pretty obvious he is very likely to upset the authority in more clearly defined jobs. We all object to the man who will persist in butting in, and very often a man is a more successful manager by keeping out of affairs than he would be by unduly butting in. I think most people will be inclined to agree with that. It is an important point in any organisation to so arrange things that each man has a perfectly clearly defined line of authority, which is not touched, or over-reached by any of his colleagues.

Mr. F. J. Burns Morton: Major Urwick, in his paper, has made a valuable contribution to the theoretical side of management. Theory is not everyone's meat and, in fact, very few have a liking for it at all. By way of comment, it may be of interest to indicate the significance of Major Urwick's contribution. Every since F. W. Taylor's principles of scientific management, different writers have put forward their own principles with a most bewildering effect on

the student. Some time ago I made a study of some twenty contributors to the principles of management. The result was amazing. It appeared that every writer preferred originality to anything else. Leffingwell (1929) for instance, preferred an embellished statement of the stages in scientific method, and Emerson (1913) states thirteen principles almost at random.

To me, one of the most important aspects of this paper is the insistence on the universality of principles. This aspect was first emphasised by Jones (American) in 1916 and was left almost dormant until Mooney and Reiley (" Onward Industry " 1931) in their most important contribution, brought evidence to show the principles or organisation at work in the many spheres of war, religion, government, and industry. So far as we, in this country, are concerned, Major Urwick has made a substantial step forward by adapting Louis F. Anderson's " Das Logische " (1929) view of principles, as a process and effect—and applying this to Fayol's (1916) statement of principles.

The next point which strikes me as being of outstanding importance is Major Urwick's view as to the definition of principles. Accepting as he does the universality of principle, it is not possible, it seems to me, for him to arrive at any other conclusion than that principles of organisation, like principles in ethics, are but guides to conduct. The more one becomes acquainted with industrial organisation, in all its variations and inconsistencies, the more one realises the impossiblity of stating principles either as immutable laws or categorical imperatives. Naturally, a principle may be a fundamental truth, an unquestionable general law, or a set of rules to guide procedure.

Long before I read Mooney and Reiley, I delved into other fields of study to find some guide or parallel on which to work. While so doing I studied Clausewitz and Foch who attempted, each in his own way, to develop a science of war, and came across Verdy du Vernois' statement " to hell with principles, what is the problem ? " Principles in industrial organisation must not become, like statutory laws, rules that must be adhered to on pain of severe penalty. Rather, they must serve first as pegs on which to hang ideas, and later as rules which can be followed with profit, provided they are fully understood. For instance, Major Urwick, in an earlier lecture, indicated Fayol's principle of centralisation, which of course means nothing in itself and only becomes significant when the degrees of application are fully understood as they apply to centralisation and decentralisation.

Another thing made clear in the lecture is the primary insistence on purpose—being the definition of the problem. Organisation structure must be devised on the job to be done, not the reverse. In a business investigation, as with scientific research, the problem

in the first place cannot be clearly defined. It is necessary to start off with a vague purpose which gradually becomes clearer as the investigation proceeds. This means that solution is quicker and more reliable when we return again and again to define the fundamental purpose. Somehow in the the business world to-day, there is a distinct dislike for theory. The concern is for systems, devices, and mechanisms for making money—for investments with stated return in £ s. d. yet theory is of outstanding importance in matters which do not primarily involve stated systems. Major Urwick is, therefore, to be congratulated on pursuing a lone furrow which I believe to be of fundamental importance.

Naturally, Major Urwick has said a number of things on which comment and question can be raised and I will confine myself to two further points. First, what is the function of the comptroller in American industry and can this be applied to the structure of organization in this country? Secondly, along what lines can research and development best be organised within the business unit? In this latter question would it be sound to have centralised research, and if so, should this be controlled by the comptroller? Arising out of centralised research is the question as to what should be covered. For example, should market research, time service planning, accounting systems, etc., be brought together for the purpose of controlled and co-ordinated development to be treated as a staff function?

MAJOR URWICK: I should like to endorse what the last speaker has said about Mooney & Reiley. Mooney is an extraordinary character. He is the president of General Motors Export Co. He was appointed to that job when he was about thirty-four or thirty-five years of age. He developed a flair for organisation. They have more understanding of formal organisation in that company than anywhere else I know. They have certainly a difficult problem, because their branches are scattered all over the world.

The book that Mooney wrote with Reiley is the only serious attempt to study different forms of organisation comparatively. Mooney himself is a Roman Catholic, and his use of information on the structure of the Catholic Church is a point of special interest. I was always fascinated by the way he brings out, for instance, the practice of the Jesuits. The Vicar General of the Society of Jesus occupies one of the most powerful executive positions in the world. He is elected for a term of years by the Order. He is held utterly responsible for any decision he makes. But he is not allowed to make any decision of importance without obtaining *first* the advice of the Council, a small body which is appointed quite independently by the General Assembly of the Order. On the other hand the Vicar General cannot evade responsibility for his acts or

decisions by pleading the advice of the Council. No matter what they say to him, he is held entirely responsible for what he does. The man occupies the highest position in the most disciplined and despotic Order of the world. But there is this principle of compulsory staff service which he has got to use, this advcice which he must seek before he acts. I thought that was a very interesting feature in organisation, and a possibility which is not perhaps generally known or contemplated. You can make it compulsory for an executive to take advice before he acts without relieving him of responsibility.

Another very interesting thing that has happened recently in the field of organisation is that a Committee of three persons have submitted a report to President Roosevelt which is likely to revolutionise the structure of the government of the U.S.A. in the next twenty-five years. This report is shot through and through with principles and ideas drawn from scientific management applied to industry and carried over, in this way, into the field of public administration. It is the first time this has actually happened in the case of the government of an important country. I cannot say how far the matter will go if President Roosevelt does not remain in the Presidency. But I think that the report will endure as a classic document on the machinery of government.

About the function of the comptroller—the best thing on it I know of is the chapter on the subject in the Handbook of Business Administration. But I think we may become confused if we associate the comptroller with a central research department. The comptroller is essentially the figure man of a business. As I understand it, the comptroller in America carries out a combination of the duties allotted in this country to the secretary, the cost accountant, and any other person who is keeping figures. The comptroller deals with all figures, and the most important point in making his function work well, is that he should never attempt to influence policy. The minute he tries to interpret his figures, and thus throws his weight on either side in an argument about policy, he destroys his authority as the presenter of figures—as the man who collects and presents figures quite objectively and as economically as possible.

With regard to centralisation of research, I think it may be necessary, particularly with smaller businesses. But in any effectively managed business, the whole of its executives should have learned to look at their jobs from the research angle. It is doubtful, taking the long view, whether centralising up the research activities, is the right way to secure this. I believe the right way to go about it, particularly with a large organisation, is for each one of the departments to provide for the research necessary for its function.

In addition there should be a number of people in a true "staff" relationship, whose job it is to collate the results of these researches and present them to the higher executives in a form leading to co-ordinated decisions which take all the research work done into account.

I am touching now on the dynamic side of organisation rather than the static side which was the subject of my paper. We should always recall that a decision is "a moment in a process." We are all inclined to draw pictures of ourselves as important business executives coming to decisions. There is too much dramatisation of managing directors. Very often, their decisions are made for them, and I speak as a managing director in my own business. I feel sure that three-quarters of my decisions come to me ready made. I should like to thank Mr. Burns Morton for his interesting contribution to the discussion.

Mr. F. J. Burns Morton: May I add another viewpoint to Major Urwick's remarks? If we assume an ideal organisation with complete staff co-ordination then obviously a centralised research department is unnecessary. On the other hand, experience indicates considerable imperfections in practice, with the result that sales, production, purchasing, accounts, etc., each retain their information as if it were their own personal property. It would seem that unless there is a staff department collecting and collating all relevant information decision may be arrived at with incomplete data. Then again, research itself should be co-ordinated and properly directed in order to avoid the production of things unsaleable and to prevent the large scale selling of unprofitable productions. There is a tendency, especially with research and investigation, for each person to pursue separate lines without communicating these until success has been achieved. Without free co-ordination between the executives there is a danger of overlapping or of pursuing barren investigation.

Major Urwick: Referring back to the point of understudies and the point of co-ordination across the line, it is really remarkable in well organised business to note the degree to which the relationships do not all run up and down or run straight across. The diagonal relationships are very often the most important of the lot. For instance, an assistant to the production manager can go to a foreman of another department and can discuss a problem without worrying about the "official channels." Neither of their chiefs will worry about the "official channels" either. I always remember from my army experience that "official channels" are something into which to plunge when you have failed to do the job in a straightforward, human way. They are not a means through which you do the job all the time and I would like to get people to understand that more clearly. You must always have "official channels," but it is far

better to do the job directly and personally and merely confirm it through official channels after it is all done, than to try to do it through the "official channels" in the first instance. The job never gets done if everyone starts by working through the "official channels." There is traffic congestion.

MR. SPENCER: Is it possible to start from the fundamentals, and build up a business on those lines, or is it necessary by painful experience to build up a business first, and analyse it afterwards?

MAJOR URWICK: I was once given a job such as Mr. Spencer describes. A man had bought an invention, or thought he had bought it. It was rather an ingenious invention, and several models had been made. He had made up his mind he wanted to use this invention for a particular purpose. He thought he could raise the capital, and he handed over the thing to me and simply said: "Now, can you plan this business for me?" We settled down and we costed the thing rather clo ely. We also did some elementary market research on restricted samples. We worked out what sort of factory we had got to put up, what sort of staff we wanted, what sort of sales force we should want, what trading capital it would require, and then we worked out the stages of growth for about three possible assumptions—assuming it went about as we expected, assuming that it went better than we espected, and assuming that it went very much less well than we expected. We calculated that in eighteen months or two years, the period of outgoings should stop, and the business should break even. After that it should begin to make a profit.

Of course this was all supposition. Unfortunately, the gentleman for whom we made this report proved mentally unstable, and it was impossible to test the assumptions in practice. But I believe that it is perfectly possible to take an article and plan a business from that article. I do not mean to say that it will work out exactly according to plan. But I suggest that the business will develop better with a plan, than by just letting it grow and trying to meet the difficulties as they arise.

Take an ordinary kind of problem,—Shall I take on a sales manager or not? Has the business reached a stage to justify a sales manager? We said in the plan perfectly definitely that the first man they should take on must be a sales *and* general manager. At such and such a stage we thought that they should take on a sales manager, or alternatively, they should take on a new general manager. It would depend on whether the first man had developed sufficiently to be made into the general manager or not. In any case, we thought that the original general manager should be primarily a salesman.

It is possible to plan theoretically in that sort of way. We can do a great deal more deliberate planning than has ever yet been contemplated even in a new business. Much waste of money would be avoided if the people with a commercial "flair," who build up businesses from nothing because they have got a commercial "flair," could be induced to take a little advice in planning those businesses from the beginning. They would save a lot of sacking, to start with. A great amount of experiment goes on with the lives of human beings, because their employers do not know what they want. They will try to buy the Archangel Gabriel for £500 per annum, and when they find they cannot do it, they dismiss the man because he is not an Archangel. They ought to dismiss themselves for imagining that Archangels can be bought for £500 a year. First decide what you want, and then, whether you can possibly get it at your price.

MR. BROOKS: Referring to this organisation plan, I have seen quite a great deal of it and read one or two books on the subject. It always seem to me to be a simple matter to organise a business which is going to make some definite article, motor cars, tyres, or something like that. There must be quite a number of businesses which are always making something different—the character of the product changes almost from week to week. Well, that leads to all sorts of difficulties. You get an organisation, and you get a particular job to do, and you try to put it through that organisation. It gets planned, it goes down to the shops, and nothing more is heard of it, it just stops. Supposing you investigate the matter, you find that nothing can go on until a certain part has been made in the capstan department. In the capstan department you find three or four machines not doing anything. You can go to the foreman, and find that these machines are not doing anything because there is difficulty in the first operation that has got to be put right. In a small business it is usual for the capstan foreman to go to the rool room foreman and say, "This does not go, but if you do so and so I can get away with the job." When the department grows, you come to the point when the tool room foreman does not know anybody. One day you get someone in the tool room asking the foreman: "Just grind this for me, I want to get the job away;" the foreman says, "Who are you?" and does nothing. All these theories rely on the fact that the individuals work for the business, and not for themselves. The tool room foreman who has been with the firm for fifteen years is not too affable with the man he has not seen before.

In the plan for an organisation of any business you have everyone connected to somebody higher or lower, and although you say that official channels are not used, they are used, because you get as lot of individuals in fairly big businesses who have no other means of obtaining information except through their official channel.

They have only just arrived, and it may be necessary for a fellow who has been there a few days, to have something done quickly to get the job running.

I think that set of circumstances calls for an individual in the plant who can do the exact opposite to what you said at the beginning of the lecture. He must please himself what he does and when he does it. He goes round the plant—when he finds the fellow in trouble, he finds out what the trouble is. When a new machine is supplied, which will not go—and that is not an unusual thing; it happens frequently—he goes down and has a look at the machine and sets it right. He discards everything else for the time being, but that particular job which must be done. There is an opening in every big organisation for a fellow like that. He simply goes to the point where there is the most trouble, where something has got to be done, and does it. He has got power to override everybody on this job. I know you will not agree there should be such a man, but I am quite sure from my own experience that such a man is invaluable in any organisation.

MAJOR URWICK: Well, Mr. Brooks, I think that is a very valuable contribution, and I am not sure that I disagree with it entirely. What I do feel is that it is terribly dangerous to let anybody do that sort of job, unless he is held responsible to the managing director or the chief executive. I have seen a case of a production chaser such as you have described, who was always putting through urgent orders, and cutting the factory production in half by not knowing when he ought *not* to upset the general plan. He would come along and say, "I don't care what you say, this order has got to go out," and so it went out. The urgent order was delivered to time; but there were about 10 other important customers disappointed because the whole general planning of the place was upset by the urgent order chaser. There is room in almost every organisation for the kind of man who does see that the job gets through, but I think he is dangerous as a normal arrangement, unless, like the staff officer in the army, he is in close contact with the principal and is thus in a position to judge the position as a whole. I quite admit that he may be of practical value, but I think it is a temporary phase. I think ultimately he will be in an official position as a "staff" officer or "assistant to" the principal.

It ought to be somebody's job in every business to look after the new man a bit when he is put on. A new man in any organisation should be carefully inducted for his sake, and for the sake of the organisation, because it costs so much if it is not done. I know that it does not always happen, but I also know that there is often waste where it does not. It should be done, just in the same way that they do it in the army. There you are told everything you have to do—where to get your rations, where to get your hair cut, and so on.

I do not say that the army is ideal by a long chalk, and I think a great deal can be done much more humanely than is usual in the army. Industry has the enormous advantage that you can go home and get away from the sound of the foreman's voice. You may only change it for another voice, but that is a matter of personal choice.

I entirely agree with you that, particularly in the medium sized or smaller business, it may be very valuable to have the sort of man you have described, but ultimately I think he should have his little square on the organisation chart, and should be called whatever title you develop for him, assistant to production manager, or something of that kind.

I believe that every organisation has far more need than is usually realised for persons whose sole job it is to see that work does get done. At present we are always setting up vast structures of committees. There are all sorts of committees consisting of about half a dozen people who need to know what the other five are thinking about and doing. It never occurs to us to take some intelligent young man, and say, "Just go round to those half dozen people and see what they are doing about this, and that they all understand each other." I believe we should save a lot of money in business and a lot of discussion if only we realised that co-ordination is a job and people ought to be assigned to do it. It can be done, but there again at the moment, as you say, if some young man passes instructions to the tool-room foreman who has been in the works fifteen years, for something to be done, the foreman will just say, "You get out of my tool room." That again, is because in industry we are not yet sufficiently accustomed to the idea of clear-cut organisation, and that people who have jobs to do should be helped to do those jobs irrespective of their status. I think in organisation knowledge, we are at least fifty years behind our technical and mechanical knowledge. We spend an immense amount of money on research in chemistry, engineering, and every aspect of the physical side of industry, but we spend very much less on the sciences bearing on its human side, which might teach us to adapt ourselves to that incredibly intricate mechanism, a modern factory.

MR. PAUSED: In the organisation of a good business you will find it works as smoothly as possible. That goes right away down from the head to the lowest individual on the firm. Now, how is that done? It is done by means of organisation which starts from the managing director. In all cases you go right away down the scale having an understudy, so that if one man should happen to be away the business does not stop. The records are kept and the understudy and the one above him are familiar with the thing day by day and you find that the smallest boy in the whole business is just as well looked after in that respect in this way.

Discussion, Sheffield Section.

MR. J. H. BARBER (Section President, who presided) : We have listened to a very interesting lecture from Major Urwick on what I think one might call a critical analysis of manufacturing activities.

He has dealt to a large extent with theoretical principles, not as applied only to one industry, but such as might be applied to almost any industry, and he has explained that there is nothing dogmatic about what he says. He realises fully that each industry has to fit itself with its own particular organisation. What is satisfactory for a large organisation employing 10,000 people would be overwhelming for one employing 500.

It is very difficult, of course, to debate a subject of this character until one has had time to think it over very seriously, but one can pick out a point here and there. Major Urwick said that he felt no one man should control more than five or six executives. That would want very careful analysing, and one would have to read the context to know what precisely lay under that. But one cannot help thinking that this kind of thing has got to be reduced to some sort of order as industry goes on. On the one hand, you have your trade unions—fairly highly organised and, on the other hand, you have selling organisations—also fairly well organised—and both tending to develop along more strictly organised lines. I suppose the natural outcome of that will be a fairly strict sort of organisation that aims at social amenities and conveniences rather than the terrific struggle which we know to-day. Perhaps, as time goes on, the stress of competition will be ruled out to some extent by an organisation which places every unit in proper order, without destroying the incentive of promotion that adds to each position its own significance and importance.

Major Urwick started by saying that he did not discount personality and drive. We all know that the origin of most businesses is simply a matter of personal drive. Some fellow is content to work sixty or seventy hours per week—he has got a clear brain and the proper personality—and builds up the nucleus which is then made into a company. Direction is taken over by a board of directors, and a large corporate structure is superimposed upon the foundations created by that one man's personality and energy. Do not let us forget that this great enterprise is one man's creation. We all know businesses which have been originated by men in fairly early middle life, which owe their very existence and all their prosperity to one man. So, with all the systems in the world, we must not lose sight of the fact that the main element is still the personal factor.

A lecture such as to-night's makes you think, and it is essential that you listen to treatises of this character if you are really to keep up with developments and realise your ultimate objectives.

I would just like to say that I was very interested in those two triangles on Mr. Urwick's chart, and I would call attention to the fact that the case of the lower triangle was manufacture—all the rest was super-structure. That, I think, is very interesting.

MR. CLARKE : In the organisation of any great business you have two functional things—a supply of material and a supply of workers. The difficulty these days is the absence of material and the difficulty of getting it, and secondly, the absence of trained workers, and the competition between business organisations in securing the services of those available. I suppose the personnel manager would be the man who would be concerned with the training of the personnel. I have an idea that training is better provided for in these days than it was a few years ago. But it is a very important part of industry which has been neglected, in the immediate past, and now more attention is being paid to it.

I can't help thinking that everything is like the stones in a bridge —when one is weak, it has to be propped up by the others, and lessens the strength of the bridge. I should like to feel in any works for which I was responsible that individuals must deal with the various aspects of management, rather than a committee. But I think that there is something to be said for committee work, if it is not committee management.

MAJOR URWICK : I very much appreciate Mr. Clarke's comments. Of course, I was outlining a very large subject within a limited space of time, and I was particularly and purposely keeping it dry and unhuman because I wanted to talk about organisation structure. Of course, the personnel manager is responsible for training and education, and I personally think that no business is going to make very great progress in the future unless the managing director is very interested in the personnel department. I am not particularly concerned with canteens or other provisions of a welfare description, which do not bear particularly on the work a man does in the factory. I think there has been a very great deal of false paternalism in the past mixed up with the proper work of the individual as an employee. But, the welfare movement in the past has given us to-day the body of thought which is looking after the worker in relation to his work—not as regards his house, his play, etc. And in relation to his work, he must have suitable *and encouraging* conditions, if he is to do his best.

I quite agree that the question of training is of fundamental importance. Although it is many years since I was in the army, I still remember with appreciation the time and attention that the army gives to training, even under the stress of war. Army practice, as compared with the attention given to the subject by industry,

sets up in my mind a comparison which does not come out in industry's favour. I think industrialists have lost a great deal by failing to realise that they cannot go into the labour market and buy what they want; they can only *make* what they want.

The second point is very interesting. In a modern functional organisation, the various functions are interlocked like the stones in a bridge, and it is one of the weaknesses in modern organisations that the strength of the bridge is the strength of its weakest function. I would add that committee work is valuable as supplying both an educational factor, showing people the viewpoints and methods of other functions represented in the committee, and secondly, as providing each function with a knowledge of the general plan, so that if there is a weakness in that plan, it can be adjusted at the start, and not be allowed to develop later in practice.

On the other hand, I do not think we should be ashamed of dealing with the educational issue directly instead of having to hide what we are doing by appointing under a committee. My own personal dislike of committees is founded on the fact that I believe the true "staff" relationship should be considered and developed in the interest of industry. The tendency at the moment, whenever there is a job of co-ordination to be done, is to appoint a committee instead of selecting a suitable individual and telling him to look after it. A committee is a very costly unit. It costs, while it is sitting the total of the salaries of all members, then there is the expense of secretarial work, and so on. I believe that many of the committees we find in industry are merely the result of inertia and mental laziness. People will not trouble to think out precisely what the job is that they want done and give an individual that job to do.

Nine times out of ten, instead of appointing a committee it would be far easier to send a young assistant round the departmental heads to co-ordinate their views and draft a memorandum. This could then be circulated saying, "Is this what you mean?" and recirculated till everyone was in agreement. Such a procedure may take ten hours of the young assistant's time, but it is less costly than half an hour of the committee's time.

Again a committee dies every time it rises; it goes out of action until it sits again. We all behave in a completely different way as members of a committee than we do as individuals.

MR. MENSFORTH: Major Urwick said that we may have to look to more highly organised sales organisations. But I find that the more highly organised selling has become the more selling costs have gone up. They are a bogey to manufacturers.

Taking a particular case, is it more efficient for a foreman in a department to look after 100 people with no responsibility other than to see that they are doing their job, and to have another man

responsible for inspection, progress and so on—or to have a man in charge of 40 people, responsible for everything that goes on in his department? The question that has just been discussed of co-ordination presents a point of some difficulty. Major Urwick suggests using young assistants as co-ordinating influences. Such experience as I have had shows that, actually, the young assistant cannot do the job because of natural jealousy that occurs in every large organisation.

MAJOR URWICK: I think those are three very helpful comments. First of all, Mr. Mensforth brings forward the question as to whether the foreman should have the entire responsibility for his job. Personally, I feel that the foreman should be made a more responsible person, rather than a less responsible person, and should be educated up to that responsibility as far as is humanly and reasonably possible. But I think the underlying argument that you cannot expect a foreman at £4 to £5 per week to possess *all* the necessary qualities cannot be gainsaid. You cannot get the men of specialised knowledge who are required for the effective management of skilled work in modern industry for that wage. Therefore, properly organised functional departments can be of enormous assistance to the right type of foreman in handling various special aspects of his work. I think too that the modern type of foreman appreciates the help of well-organised specialised departments, and is more ready than he used to be to recognise his own limitations—which are those of any individual.

Mr. Mensforth quite properly called attention to the fact that, the more highly sales have been organised, the more they have cost. I entirely agree with him that the costs of distribution in this country are simply appalling. Nobody is attempting seriously to *cost* distributive processes at present, which is perhaps, one of the reasons why they are so expensive. You have a factor there which you have not got in perfecting your productive organisation. In manufacturing you have not the constant and direct competition with other suppliers, pushing you on from expense to expense, by sheer competitive pressure, as you have in distribution. I also think that a great deal of our present distributive expense is in itself almost valueless, but that is another aspect of the problem.

Turning to Mr. Mensforth's last comment, of course, I entirely agree with him that it is almost impossible at present to establish the ideal at which I was hinting, of a widespread use of the rare "staff" relationship in industry, because of jealousy. I think the reason for that is not very far to seek. Industry does not distinguish between function and status. Immediately, therefore, a junior starts carrying out some perfectly well-defined function which people have formerly associated with a more exalted status, he

gets hit over the head for trying to enlarge his own status illegitimately. Of course, juniors who invite this treatment are not unknown.

I do believe that, if we could solve this problem of defining status —it is defined in the Army by rank—we should have gone a long way towards better relationships, wider delegation of functions and closer co-ordination. When you think of the specialised knowledge that is required to run a modern business at anything like competitive efficiency, the burden of co-ordination thrown on the chief of chiefs is about 300 or 400% greater than it was fifty years ago. But we have done nothing to improve our machinery for dealing with this additional burden of co-ordination. You find chief after chief in business to-day who is so busy with filing cabinets, that he cannot see his foremen or his factories, or deal with the realities of his industry. He is always in his office. I never met a General, who knew his job, who spent more than about one and a half hours a day in his office. He spent the great part of his time with troops in the line, looking at dumps and supply arrangements, and so on, seeing how his men were getting on. And *the* job of every chief, be he general or managing director *is* to see how his men are getting on. All the countless specialist details in the general's job were carried out by the "staff" officers, who were the subordinates or equals in rank of the men to whom they passed their chief's instructions. Everyone understood that they were not superior officers, that they were not giving you *their* orders. They were there to give detailed effect to the general's orders.

An enormous amount of our trouble in industry could be eliminated if we could once get people to understand that function and status are *not* the same thing. Status is built up out of good service in the past, and out of a whole series of other considerations which may have nothing to do with a man's function at the moment. Function is simply the job that a man has to do at that particular moment. I believe that a very large proportion of the ructions that take place in business life could be eliminated once this was understood. They are not solely due to egotism or selfishness. They are due in a large measure to a lack of co-ordinating machinery, to the absence of individuals whose duty it is to see that frictions and misunderstandings and wrong relationships with other people are corrected promptly. Wherever I have come across serious rows in industry in 99 cases out of every 100, they have been due to faulty distribution of duties, or to faulty procedure. In scarcely one case in 100 were the parties concerned impossible to work with.

A VISITOR: As one who has sat on industrial committees, I agree with the comments of the lecturer. One of tne occasions, however, where industrial committees may be of service is in the case of a new manufacturing process where, very often, discussions

between the engineering and process departments can be of advantage. They can also be useful in such cases as factory safety.

One point which the lecturer did not mention is the question of key-men or executives. I do think that it is always a sound policy, in relation to every position, whether it be a foreman or manager, or even a workman—where a workman is carrying out a specific duty—for substitutes to be trained, in case the leader or specialist becomes absent through illness. Then there is no disorganisation in the department. Even with regard to workmen, the workman may have specialised skill in the particular job. If he happens to be absent, very often that particular job will crop up and there is trouble. I was also very interested in the lecturer's comments about responsibility, and his last few remarks about rows. I once came across such a problem, and I think this question of ructions is one which every executive might put in front of his desk every day. The first sign of a man's incapacity for a job is his desire to push the stigma of failure upon others.

MAJOR URWICK: I agree with the comments of the last speaker. In thrashing out the question of a new process about to be installed a committee is practically an essential instrument. But I would prefer to call that sort of committee a conference—it may seem an invidious and unnecessary distinction, but I think there is a definite distinction between conferences and committees. Certainly, also, in safety first work in a factory, committees are valuable, but, there again, it is their educational function which is important. I entirely agree with the speaker's comments about alternates. I knew a manager who had had an assistant working alongside him for fifteen years, and when he was eventually absent through illness, the assistant was absolutely unable to deputise for him. Opportunities should be made for alternates to assume the responsibility of others, during holidays and on other occasions.

A VISITOR: I think there are very few large firms where some such arrangement as that outlined by Major Urwick is not in force. Some of us may think the charts which we have seen to-night rather terrifying in view of the number of sub-divisions of responsibility. But I would like you to regard them as constituting a very comprehensive illustration of the principles Major Urwick has been speaking about. Perhaps organisation may be regarded, like engineering, as a science; but a science on a somewhat lower level than the exact sciences and with less particular limits. It seems to me that this is one of the ways in which we can look at these charts on organisation. We must adapt organisation principles to suit the requirements of any particular factory. The reverse of the charts is the question of the people who fill the positions shown on them. I think that the choice of the right individual for a particular job is of very vital importance, and particularly so if

your organisation is one which operates on functional lines. Those operating on such lines may give a very great amount of trouble unless you have a staff with broad minds—charitable minds. I have seen quite a lot of trouble from this question of functions. I am very glad to hear what Major Urwick has to say about committee management. I am entirely in agreement; I think no committee system of control can be any good. Give a man individual responsibility and let him have the necessary authority to make decisions and see that they are carried out and, with the right man in the position, he will see it through.

MAJOR URWICK: I am sorry if the charts looked terrifying! But think for a minute what happens if you have a one-man business—who is to carry out all the functions? Each of them is essential. It is done simply by division of the one man's time instead of allotting functions to several different people. If you have 3,000 employees, you must to some extent, specialise each main function under one man. But exactly what the tolerance allowed between that man's job and the next man's does not matter, provided you do not break the eight chief principles.

With regard to the span of control, what I said needs some elaboration. One man should not attempt to supervise more than five or six other people *whose work interlocks*. There is a reason for this. The moment you have two or three men whose jobs interrelate or interlock one with another, you have to control not only A, B, and C, but also the relations between A and B, B and C, and C and A. The number of these relationships goes up by geometrical progress and not by arithmetical progress as you add further subordinates.

I entirely agree about the choice of the right man. That is a point on which science at present has very little to say that is effective in the day by day responsibilities of the industrial executive. As Professor Haldane said the other day—it may be 200 years before experimental psychology can give us clear guidance on such a question as the selection of people for posts of responsibility. It has taken roughly that time for biology to develop into an instrument of real practical value in animal breeding. Experimental psychology may develop a little faster. But to-day it is roughly in the same position in its evolution as an exact science, as was biology 200 years ago.

A vote of thanks to Major Urwick concluded the proceedings.

Discussion, Preston Section.

MR. WILCOCK : Don't you think, Major Urwick, that the greater use of the functional contact would lend to a happier business than we otherwise get ? If you have these various departments in the modern organisations where the respective heads of departments have certain duties, no matter what branch of the business they may be in, or the size, they are too apt to work to the written rule. We all know what would happen on the great railroads of our country if the various department heads and operators of the railway systems had to work to rule—the thing would be in chaos. The success of the whole system is, I think, due to the high quality, or the fuller use of the functional contacts. Regarding the grouping as illustrated by your diagrams, do you not think that it has a tendency to create watertight compartments to a far greater degree than ever experienced in some older types of organisations ? It has often been said that the modern studies of production have made their progress on the old watertight compartments. Are we not to-day creating far more of this class than in the past ?

MAJOR URWICK : We are at the moment in a position when technical development of machines and processes, the whole enormous burst of scientific knowledge about material things which has come about in the last hundred years, has forced upon us an enormous increase in specialisation. You just cannot know the best practice in respect of any one of the 18 or 20 aspects of production unless you have a pretty high grade specialist. Immediately you specialise something that has been done before as part of general knowledge of the manager, you always get resentment.

The best example I know is the arrival of Florence Nightingale at Scutari. All Florence Nightingale would say was " You army doctors don't understand nursing." It is a special function which should be carried out by women specially trained for the purpose. It is something different from being a doctor. Florence Nightingale was carrying out a new function in organisation. It is going all over over industry. There is a certain amount of resentment among the men whose authority is subject to this specialist check. The specialist draws up a whole host of rules—the top management in trying to introduce specialisation draws up rules. Two or three get rapped over the knuckles and everybody falls back on the rules. No organisation can run on rules, only on the understanding of principles and proper give and take over principles. If you think about it in that way you will be disinclined to resent the introduction of new functions quite so much.

In the military form of organisation they have all these functions, and are working perfectly well with line command because the machine has got running—people are accustomed to it. You will find that these different specialised functions will gradually fit into their proper places in the picture as we get accustomed to this idea.

MR. WESTALL: Regarding non-productive labour in the form of general labourers, how are wages accounted for? They are apt to be overlooked in many cases where accounted for in general oncost or department oncost.

MAJOR URWICK: Broadly speaking, where you have got high maintenance charges for general labour, we always go on the principle that you must set a standard to start with. It is absolutely useless to turn in accounts and suddenly find you have a big charge for maintenance labour, and then say it is too much. What we always try to do is to say "What is a proper allowance for maintenance in this factory, what ought the maintenance to cost?" Relating to general charges, it may vary enormously with conditions. In one factory, you ought to relate to general production, or to machine hours, or to some other factor. Every case is different. A factory is a live changing thing in itself. Having determined what is the accurate index against which to measure maintenance cost, and having worked out the proper standard of costs in that factory, there should be weekly or monthly controls to show whether it has risen above the standard. I get a little tired of cost accountants when they are terribly pleased when they have produced what a thing has cost. It is what it *should* cost that is important—the relation of what it has cost to what it should cost.

MR. HARRISON (Chairman): Regarding the specialisation of functions, don't you think there is a tendency for the specialist in each department to regard himself as the "big man"? The tendency is to have a man under him and he hands on notes, "Please do so-and-so—I want such and such a thing doing." The man underneath him hands it on to someone else and it goes down the scale. I think there is a tendency for too much specialisation, in departments, at least.

I will give you an example. We sent a telegram last week to a very important firm, saying we were requiring goods very urgently which had been on order a long time. We asked for urgent delivery, stressing the point that they were holding up delivery to our clients. On Monday night we received an advice note that these goods had been despatched. On Tuesday morning we received a telegram replying to our telegram of last week saying they were sorry the goods could not be delivered, but they were doing their utmost. The advice note arrived before the telegram. This happened in a very large firm which you all know and possibly deal with. It

is a very well organised firm. Probably the despatch department handed the telegram to some other department.

MAJOR URWICK: I am afraid the cure for it in modern organisation is more specialisation rather than less organisation. Personally, I think that the real cure is to specialise the customer. I do not like this dividing offices up like factories into serial departments. The ledger, order or traffic department writes letters to customers—the business is speaking with 15 different voices. I must say I have been responsible for reversing the whole of that process and saying "sub-divide the customers and not the work"—let one clerk be responsible for all contact with individual customers. Do not split the responsibility. Writing to customers is just as important as your sales. You want to be able to nail the responsibility for bad relations with customers. I have tried this in practice. Due to the breaking up of offices into serial departments, they lose sight of the fact that the offices exist to serve customers. If you have groups of customers, you can go straight to the man responsible for any customer. The most important feature of the sales ledger is that a statement goes to the customer. Someone should be responsible for each customer, but of course one gets mistakes. We once bought a carpet which was wanted rather urgently. My wife got rather excited when it was six weeks behind delivery date. I told her she should go to the shop, and she would find it sitting on the dispatch bale addressed to her, and so it was!

MR. WESTALL: Regarding internal transport, should that be under the control of one head or should heads of departments have control of the transport in their particular department?

MAJOR URWICK: I do not think I can possibly give a general ruling. Certainly there should be a man specialising in the study of internal transport methods, but whether the actual executive control should be under that man or under department managers is a question which entirely depends on the actual facts of the given factory. There are no rules—you can only say that here is a subject which the average department manager will not know very thoroughly. It is a subject where the point of junction between departments is of great importance. There should always be some arrangement in the study of the internal transport system as a whole, but whether controlled centrally or not, the actual operation of it must depend on a large variety of factors which vary in each individual case.

MR. HARRISON: The personnel side of the business—should it be separately controlled? I do not know of the general experience, certainly we find that we have the greatest difficulty. We find very often that our workmen have children leaving school. They go to the foreman and say "I have a son leaving school, and I would like to get him in here if possible." How would it be possible with a personnel manager?

MAJOR URWICK: There is no bribe for which the human mind falls more quickly, from the managing director to the man in the shop, than to exercise patronage. It is not a bad thing that the foreman or workers should come along and want a boy to get into that company. With modern conditions, with trade union structure, there should be someone concentrated on hiring, firing, transferring, promotion—conditions applicable to the personnel of the company as a whole. In the first place, I do not think that the department manager has time to deal properly with personnel. He certainly has not time to study modern practice. In the second place, I do think the worker likes to feel there is some court of appeal, although I am not suggesting that you should interfere with the foreman's proper authority. I believe that bad relations are caused not by things like wages, but by little grievances in the shops.

Wherever I have seen a widely established personnel department, the factory becomes happier, and gets a better class of labour. If a foreman or a worker comes along, the employment manager should consider the advisability of seeing the boy. He may not take the boy, but if he refused to see him, he would be definitely blind. He would upset the man to save half an hour of the company's time. That half an hour is very extravagently saved if you have upset a good employee. A properly run modern employment department can do a tremendous amount. I think that in every big business we shall have to come to the centralised employment or personnel department, because you see after all, the labour is employed by the company, not by the foreman or department manager, and there should be somebody representing the company and the company's policy to the individual worker. Where I have worked with a personnel department, I found it an enormous assistance and not a handicap. You could go with awkward personnel problems and talk them over with the manager. In the old system where the foreman could do what he liked, his power was far greater than any individual should be allowed to exercise. We are all apt to go wrong about individuals. We are unjust when we do not like people. For every engagement, transfer, promotion, salary, I would always rather have two or three opinions. I think the personnel department provides this.

MR. LLOYD: Suppose the shop foreman calls in a specialist who is not responsible directly to the works manager but to some chief in head office. Reports have to travel to head office. One of the difficulties of organisation is the fact that the specialist is not on the spot, but, say, away in head office. The foreman feels he has set up something rather too big, and wishes he had not called up the specialist.

MAJOR URWICK: I entirely agree with you. I think it is due to the newness of this organisation and that fact that people have not

worked out proper relations between line control and functional control. If I may come to the military parallel again, there your functional specialist is always under the line man immediately, but the line man understands he must not interfere with him on his speciality. No commanding officer can give an order to his quartermaster about the supply of rations which infringes the general relations. There you have a man who becomes a warrant officer and specialises in the supply of ordnance and food and does not expect to go back into the normal line of promotion. He is not exactly a specialist in the sense of an engineer or an accountant, he is a man from within the line who is allowed to specialise on one thing. There is another kind in the army, like the transferred officer who is sent away for a short course of training and specialises for a period but expects to go back into the ordinary line of promotion. We have a long way to go in industry in thinking about relations between professional people and people who are not professional of the ordinary line. I think it is most important that we should always retain our consideration of the authority of the line. I think it is equally important that the line man, the foreman or department manager, should be most thoroughly and soundly spanked if he does not use specialist help. There is every excuse if the specialist's relationships are not properly worked out.

FABRICATED MACHINE CONSTRUCTION.

Paper presented to the Institution, Edinburgh, Glasgow, London, Yorkshire, and Eastern Counties Sections, by
S. M. Reisser, B.Sc., A.M.Inst.C.E.

Scope of Paper

THE discussion of any technical paper is not only invariably of interest to the proceedings, but is also often found to add considerably to the value of the paper itself by providing additional information on points of greatest interest. The reading of the paper should, therefore, be limited to as short a time as possible—a condition which it is often far easier to define than to accomplish if the subject is to be adequately covered.

The title of "Fabricated Machine Construction" can obviously cover an immense field—not only with respect to the different types of machines in use in the various branches of industry, but also as regards the two general subdivisions of the subject itself—i.e., design and fabrication. For this reason, the paper must necessarily be of a very general nature—applying to all types of machines and dealing with only general considerations bearing on the pros and cons of welding as applied to this type of work. In other words, it can merely outline the advantages which are made possible by the correct application of this process and indicate the meaning of the term "correct" without attempting to describe the details of design and fabrication of the welding process and procedure.

Reason for the Adoption of Welding

The first consideration in the proposed fabrication of any machine is the choice of the most suitable material. In theory the term "most suitable" should refer only to the mechanical properties, but in practice considerations of price and costs of fabrication often warrant the use of a larger quantity of an inferior material providing that the strength of the structure can thus still be kept within the design requirements. If, however, the completed article can be produced from the most suitable material and at the same or even lower cost through the adoption of a new method of fabrication—then surely this method is the right one to use and, therefore, to be encouraged. Now this exactly is the contention made on behalf of welding in relation to bedplates, machine frames, etc. It is not, of

Ipswich, November 2, 1937; Edinburgh, January 19; Glasgow, January 20; London, March 4; Leeds, April 25, 1938.

course, suggested that it will entirely replace rivetting, bolting and casting which, in certain cases, will always and should be retained either on the grounds of costs or special design requirements. Undoubtedly, however, in the vast majority of cases the correct use of welding is very advantageous from all points of view.

Choice of Material

The choice of the material for the design of any structure is governed by the nature of the loads which it will have to carry and since all machines consist of an arrangement of ties, struts and beams subjected to direct and/or bending stress, the tensile and compressive strength of the material is obviously of primary importance.

It must also be borne in mind that the stress is usually of a dynamic nature—sometimes in one direction only—i.e., pulsating, sometimes in the reversed direction as well—i.e., alternating. Both kinds tend to produce fatigue cracks unless the machine is designed so that the maximum stress produced is below the fatigue endurance limit of the material and, therefore, this property must also be taken into account.

Two other properties of great importance are the impact value, since the load is frequently applied with shock, and the rigidity of the material. This latter is a primary consideration in the vast majority of cases and its importance from the cost of production point of view has been excellently illustrated by Mr. Everett Chapman of the Lukenweld Corporation, Pennsylvania, in connection with a press frame which he mentions in one of his papers. Mr. Chapman pointed out that modern mass production of forgings and stampings requires not merely quantity but also accuracy to limits hitherto unknown and, for this reason, one frequently encounters a set of dies costing some $10,000 mounted in a press costing but one-quarter of their price. The cost of the die per piece produced—an important factor in determining the price of the finished article—depends upon the number of satisfactory pieces made before the die needs re-dressing and the number of times that it can be re-dressed. Both these depend on the rate of wear which, in turn, is almost directly proportional to the deflection of the frame and moving parts of the press. Thus, even elastic movements must be restricted to a minimum, and it follows that the modulus of elasticity is of primary importance.

On the other hand, it also follows that two other properties—ductility and reduction of area—which are usually demanded in the testing of the material, are not required from the designer's point of view. But at the same time it is as well to remember that local concentrations of stress tend to be relieved in a ductile metal

whereas in certain cases cracks may be produced by this cause in a brittle material.

The usual materials used for the construction of machines in this country are cast iron, cast steel and rolled mild steel, the use of wrought iron being restricted, both from economical and mechanical reasons, for all but special purposes. In America, the employment of low carbon alloy rolled steels is becoming increasingly popular in the fabrication of machinery, but since the use of these materials in this country is still very limited, only the three first named will be considered. Typical mechanical properties are shown in Fig. 1, and only a brief glance is necessary to determine the most suitable material.

Material	Tensile Strength tons/sq. in.	Compressive Strength tons/sq. in.	Shear Strength tons/sq. in.	Fatigue Strength (Alternating Stress tests) tons/sq. in.	Impact Izod ft. lb.	Modulus of Elasticity tons/sq. in.
Cast Iron	9–16	30–50	13–16	± 5– ±8	—	5½– 7
Mild Steel	26–30 28–33	17–20* 18–22*	16–19 18–21	±10– ±11 ±11– ±12	80–90 65–75	12½–13½ 12½–13½
Cast Steel	30–35	19–23*	19–22	±12– ±13	45–60	12½–13½

* No well defined ultimate in compression the yield point is taken as the practical ultimate strength in compression.

Fig. 1—Comparison of mechanical properties of cast iron, mild steel, and cast steel.

It will be noticed that cast iron is definitely inferior in all properties except compressive strength, and that its modulus of elasticity is only about one half that of cast or mild steel. In other words, for equal scantlings and load, the deflection of a cast iron member will be roughly twice as great. This very much lower rigidity is often unnoticed in practice as the casting usually contains, on account of moulding requirements, a considerable amount of excessive material resulting in extra weight.

The properties of cast steel compare favourable with those of rolled mild steel, but it does not flow freely and is, therefore, difficult to cast. As a result, the soundness of a steel casting can never be taken for granted and it frequently happens that some four out of five have to be rejected after machining—a serious matter from both the cost and delivery points of view.

Rolled mild steel has none of these disadvantages, and its adoption for machine fabrication also results in a considerable reduction of weight since the parts are built up of plates of only the required thickness. Nevertheless, prior to the advent of welding, the use of this material for machine construction was far from general on account of the difficulty of connecting the parts together. It will be realised that both rivetting and bolting require the use of either angle connecting material or flanging for the joining of all plates lying in planes inclined or perpendicular to one another and, with complicated shapes and restricted space, this requirement usually becomes impossible either for technical or economic reasons. One would, therefore, conclude that—given an economical and easy means of fabrication—mild steel is the material which suits the designer best. This is probably one of the principal reasons which, in recent years, has brought welding to the fore, and its ever increasing use in fabricated machine construction is a proof of the advantages which it offers.

The Arc Welding Process.

The arc welding process of joining plates and sections consists of fusing the adjacent edges and filling the gap with molten metal of similar characteristics. The heat necessary to effect fusion is obtained from the arc whose function is to transform into heat the energy the electrical energy supplied by an electrical generator. The filler material is obtained from the core wire of the electrode which is also melted by the arc drawn between it and the work to be welded as shown in Fig. 2. The analysis of the molten metal of a bare wire electrode undergoes a very considerable change during its passage through the arc and, for this reason, all modern high quality electrodes are coated with a flux whose object is to compensate for the losses and thus control the mechanical properties of the deposited metal. The type and nature of the coating likewise has a marked effect in the running properties of the electrode which may, in certain cases, be also affected by the type of plant used. Consequently, most specifications contain a clause to the effect that the plant used for the work in hand shall be suitable to the particular type of electrode selected and, for this reason, in selecting a new plant, it is just as well to choose a type as universal in application as possible.

Electrodes

A detailed description of the types and functions of electrode coatings is a subject of its own and well outside the scope of this paper. Suffice it to say that a very large number of both general and special purpose types is to-day available to the designer. The former deposit mild-steel—the mechanical properties of the

weld metal varying with the particular brand of electrode used—and can usually be used for welding in all three positions, i.e., horizontal, vertical, and overhead. The latter are designed to deposit either special steels or high quality mild steel for a definite purpose and/or welding position.

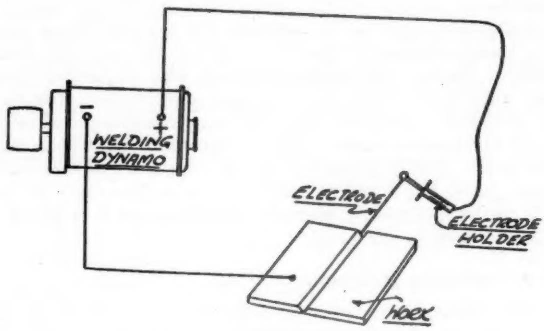

FIG. 2

Welding circuit.

The resurfacing of worn rails with an electrode depositing weld metal of a Brinell hardness comparable to that of the rail itself is a very ordinary example of the use of an electrode producing special steel quality weld metal. A more unusual case of the application of a similar type can be quoted from the June, 1937 issue of "The Welder"; ("Weld metal resistant to corrosion and high temperature oxidation.") A certain important chemical concern employed the usual type of mild steel tube used for high pressure work for carrying gas at a pressure of several thousand pounds per square inch. Although the gas itself was inert, it was found that a certain amount of condensation occurred nevertheless. The moisture collected in the recess of the joint causing corrosion and, finally, ultimate failure of the joint by leakage. The company were thus faced with the prospect of either replacing the whole of the tubing with stainless steel—involving very considerable expense—or, alternatively, having recourse to the use of special electrodes. This latter course was decided upon and a layer of stainless steel was deposited on the end of each pipe which was then machined and screwed. The repair completely overcame the corrosion trouble and the method is now part of the standard practice of this particular firm.

The special purpose mild steel electrode, although depositing ordinary high quality mild steel, offers certain definite advantages such as high speed in conjunction with correct profile of fillet, special shape of fillet, ease of workmanship in one or other welding position, etc., and its use, therefore, results in increased efficiency.

Choice of electrodes.

If all requirements of both design and costs are to be satisfied, the correct choice of the correct grade of electrode is always an important point, and one which usually presents some difficulty in view of the great variety of types and brands. All specifications usually contain a clause in connection with the mechanical properties of the weld metal, but it will be remembered that the same properties may be had from a number of electrodes of entirely different welding characteristics, so that such clauses afford only partial guidance in the matter of choice.

Until a few years ago, prior to the advent of the special purpose type, the general purpose electrode was in almost universal use and is still recommended by a number of people for all mild steel work The main argument in favour of this type put forward by its advocates is the fact that the welder is not called upon to change his electrodes whatever the welding position and —assuming this to be an important point for the sake of argument—one wonders why a similar contention has never been made on behalf of a uniform size of rivets in the parallel field of rivetting.

That it saves the welder the necessity of changing electrodes is not disputed, but the fact that it is usually obtained by means of a compromise between the type of flux required for the different welding positions and thus results in a sacrifice of efficiency, makes it an advantage of a dubious nature. Furthermore, it precludes the use of a number of joints which can be made only in conjunction with a special electrode and, therefore, narrows the scope of the designer. These considerations would tend to show that the only way of selecting the correct electrode—if all the advantages of welding are to be realised—is to make the choice in accordance with the types of joints used in the design and with a view to the welding position in which they are to be made. In other words, the fact that two or more special purpose electrodes may have to be used for one job should not be looked upon as a disadvantage and will, on the contrary, result in increased efficiency in most cases.

Welded Joints.

It will be appreciated from the foregoing that a knowledge of welded joints is essential if the right electrode is to be selected. Although many special names have been given to different types of welded connections, they can all be referred to two fundamental groups: butt welds and fillet welds.

A butt weld is usually defined as a joint in which the weld metal lies internal to the parts joined (see Fig. 3—a. b, c, and d), whereas a fillet weld is a joint in which the weld metal lies external to the part joined (see Fig. 3—e and f). With regard to butt welds, when the plates are $^3/_{16}$ in. thick or under, no preparation of the edges is necessary and the joint can be made as in Fig. 3 (a) with any good quality coated electrode.

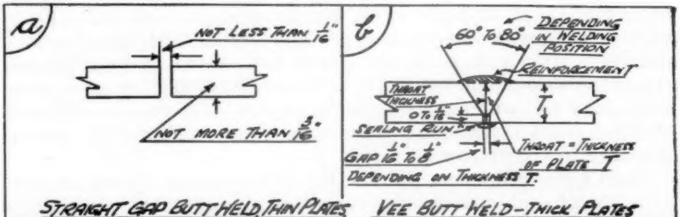

FIG. 3.

Types of welded joints.

As the thickness of the plates increases above $^3/_{16}$ in., the joints shown in Fig. 3 (c) and 3 (d), are used, but it is now necessary to pay attention to the choice of electrodes. The joint 3 (b) can again be made with any electrode and, to a large extent, also that shown in Fig. 3 (c). In the latter case, however, the ease with which the

work can be done does depend on the electrode selected and it is, therefore, advisable to make the choice accordingly. On the other hand, the straight gap close butt joint shown on Fig 3 (d) requires the use of a very special type and the thickness through which it is possible to weld successfully depends entirely on the electrode used. The joint has great advantages as regards speed, economy and decreased tendency to distortion, but this type of electrode is not yet in general use and such joints must be made only in strict accordance with the maker's instructions as to thickness of plate and procedure.

In fillet welding, although the type of joint shown in Fig. 3 (e) can be made with any electrode, it must be remembered that the shape of the fillet, the speed of deposition and the ease of de-slagging depend upon the particular type selected so that the choice will have an important bearing on the costs if the amount of welding is considerable. It must also be borne in mind that the maximum size of fillet which can be deposited in a single run varies in proportion to the guage used only up to a certain limit. If a still larger fillet is required, it must be built up of a number of runs—unless a special electrode is resorted to. This does not mean that a large single run fillet can not be made with any type, but the adoption of such a course is usually reflected in the quality of the weld unless the electrode is specially designed for the purpose. The advantages of using this latter are again reflected in the cost of the welding.

Bearing in mind that, with the normal shape of fillet and a given strength of deposited metal, the strength of the weld is approximately proportional to the actual throat thickness, whereas the cost is proportional to the volume of weld metal, the advantges of the high penetration fillet shown in Fig 3 (f) are obvious at a glance. At the same time, all the remarks in connection with the straight gap close butt weld apply equally well in the case of this type of joint.

Welding procedure.

It has already been mentioned in connection with single run fillets that the manner in which the weld is made may affect the efficiency of the joint. A similar effect may be likewise observed in the case of butt welds and it thus becomes apparent that definite procedure must be adopted in the making of the welds if a uniformity of quality is to be obtained. The word " procedure " would appear to possess many senses and has often been employed to cover up a multitude of sins and ignorance, so that it is as well to state that it is here used to denote the following seven variables:—preparation (if any) of the plate edges, gap (if any), gauge of electrode number of runs, sequence of runs, current and length of run per electrode (i.e., distance in which the whole electrode is to be deposited). This latter variable also takes into account the method of deposition, i.e. whether in straight runs or with weaving,

since it is not possible to deposit very short lengths of run per electrode without the weaving of the tip. It has already been mentioned previously that the preparation of the plates and the gap vary in accordance with different types of electrodes and it is essential that the remaining variables be likewise kept within the limits prescribed by the manufacturer for the particular type in use. The necessary information is usually supplied in the form of pamphlets, which sometimes also contain a "data card" for butts and fillets which will not necessarily apply to any but the brand for which it is made. The adoption of the use of such data cards as part of the normal works practice simplifies the costing and considerably increases its accuracy, as well as insures that the estimating department and the works function in unison. Any additional information which may be required for a special case is always gladly supplied by the manufacturers, who are at all times pleased to answer any inquiries in this connection.

Fabrication.

The facilities available for welded fabrication have an important bearing on the cost of the work—a point often forgotten when making comparisons with other forms of fabrication. Most rivetting shops and foundries in this country are fitted out with up-to-date handling and other necessary equipment, enabling the work to be done in the most efficient manner possible and, consequently, at the lowest cost. Not infrequently one finds a certain amount of welding being done in the same shops—the work in this case, however, being carried out in a hole and corner fashion. The resulting higher price of the finished article is, in such circumstances, only to be expected, but the increased costs of production are invariably put down to the welding process rather than to the lack of facilities and organisation.

When, on the other hand, one examines the position from the point of view of a properly equipped welding shop, one finds a very different state of affairs, and the increasing number of works which are changing over to welding—both in this country and abroad—is positive proof of the advantages offered by this process of fabrication. A visit to such welding shops is in itself an education of what can and is being accomplished in this connection. If an observer who had been connected with welding only in its early days were to undertake such a tour, the points that would strike him most would probably be the use of large guage electrodes for all heavy work and the rapid development of welding jigs and positioners. For although, as mentioned previously, electrodes for both vertical and overhead work are available, horizontal welding is always the cheapest both on account of the ease of workmanship and the fact that it places no limit on the size of electrode ; so that the modern

tendency is to equip the works with some form of universal rotating jigs and positioners, which enable the job to be rotated with ease and allow for the majority and frequently the whole of the welding to be done in the downhand position. The simplest form of a welding positioner, shown in Fig 4, consists of a welding table mounted on a trunion which itself is mounted on a shaft. The job is tacked to the

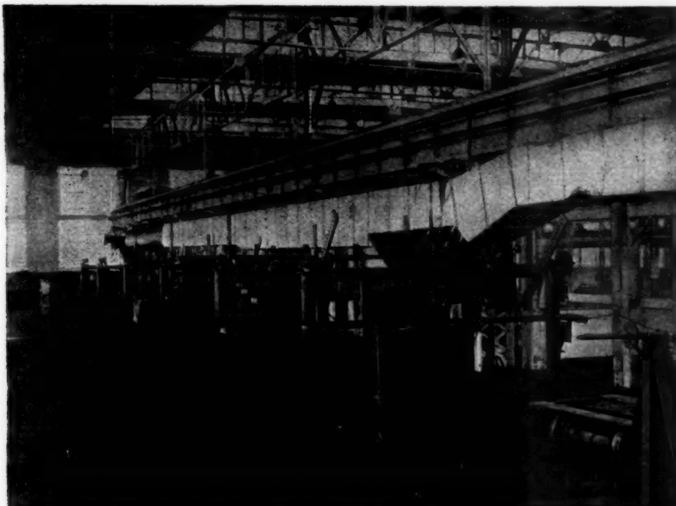

Fig. 4.—Welding positioners at the works of Lukenwold Corporation.

table and held in any position by means of a brake. Another form of a welding manipulator, shown in Fig. 5, has been perfected by the United Engineering and Foundry Co., Pittsburgh, U.S.A., and is manufactured in this country by The Davy and United Engineering Co. Ltd., of Sheffield.

(The use of welding positioners and manipulators at the works of the Lukenweld Corporation, U.S.A., The Harnischfiger Corporation, U.S.A., The Dravo Corporation, U.S.A., The American Westinghouse Co., Messrs. Wickham's of Ware, and a number of other firms was then illustrated by means of a number of slides).

Examples of Welded Fabrication in Machine Construction.

The applications of welding to fabricated machine construction were illustrated by means of a considerable number of slides depicting both British and American examples—the main advantages derived from

this method of fabrication being pointed out in the course of the description of each slide. The American examples included a heavy fabricated base plate and a 2,000 ton press fabricated by the Clearing Co., U.S.A. The British work consisted of the following examples of heavy machine components: Bedplates, gear wheels, press frames, haulage drums, shear frames, magnet cases, etc., fabricated by Messrs.

Fig. 5.—Welding positioner manufacturered by Messrs. Davy & United Engineering Co. Ltd., Sheffield.

Dorman, Long & Co., Ltd., Redcar; transformer tanks, stator frames draught tubes, etc., fabricated by the English Electric Co., Ltd.; forming and joist straightening machines by J. Bidgood & Son; puncher type slotting machines and shapers, fabricated by the Butler Machine Tool Co., Ltd.; gooseneck straightening presses, camshaft bushing assembling press, two-column speed press, etc., fabricated by The Weatherley (Oilgear) Co., Ltd., and the bogies for the 1938 L.P.T.B. new surface line stock shown by courtesy of Mr. Graff Baker, Chief Mechanical Engineer, L.P.T.B., and The Gloucester Railway Carriage & Waggon Co.

The Haulage Drums fabricated by Messrs. Dorman, Long & Co. Ltd., Redcar, are reproduced in Fig. 6 as a typical example of the advantages derived from the use of welding. It will be noticed that instead of a thick brake rim with wooden blocks, a thin rim using ferodo has been incorporated—this method having proved much more efficient than the usual type. The arms consist of two 7 × 3 *channels*

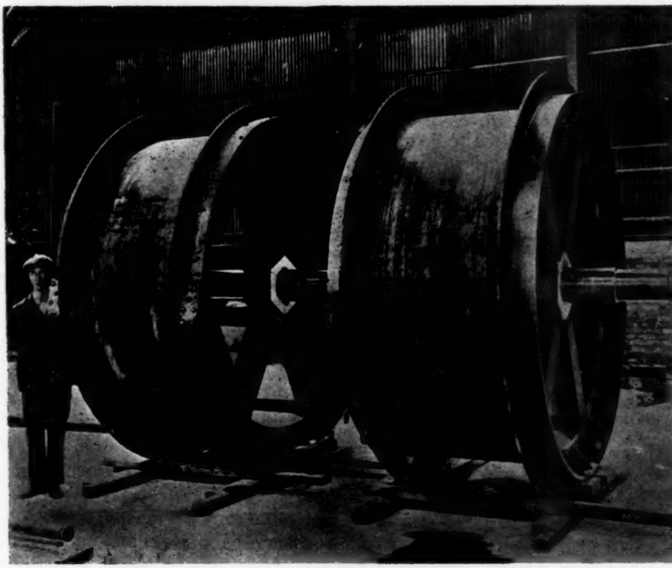

Fig. 6.—Welded haulage drums fabricated by Messrs. Dorman Long & Co. Ltd., Redcar.

welded together to form a box section, while the bosses—cut from 10 *in. slabs of steel are hexagonal to facilitate fabrication. The thickness of the rim has been considerably reduced and consists of a rolled steel plate* ¾ *in. thick. The diameter of the drums is* 9 *ft.* 6 *in., the width* 4 *ft.* 4½ *in., and the weight of the two drums and the shaft on which they are mounted is only* 9 *tons* 7 *cwts., i.e., only* 65% *of the weight of their cast iron predecessors.*

Conclusions.

Summarising the position with regard to machine construction it would appear that the use of rolled mild steel offers many distinct advantages as compared with cast iron and cast steel, and that

welding is the most suitable—and in many cases the only—means of effecting the connections between the various components. If, however, the full advantages of this process of fabrication are to be realised the electrodes should be chosen with a view to the particular work in hand and the standard procedure recommended by their manufacturer adhered to in all cases. The work should be carried out in shops properly fitted up for welding and the use of jigs and manipulators is recommended as having a favourable effect on the cost of production.

In conclusion, acknowledgments are due to the numerous firms and individuals who have been mentioned in the foregoing and who have kindly supplied the photographs for the slides illustrating the application of electric arc welding to fabricated machine construction.

Discussion, Edinburgh Section.

MR. PEET (Section President, in the Chair): Mr. Reisser has given us a very interesting lecture, and we have seen how all the various shapes are fitted and the machine parts can be put together. It is certainly a very neat job and looks to my mind to be far superior to rivetting, or any other method. There were one or two points which I wanted to put to Mr. Reisser. One was the grinding of the joints—whether they were actually ground off, or whether they were left for the painter to fill up when the articles were finally finished?

MR. REISSER: That depends on the type of weld: in the case of a fillet with a concave profile as illustrated by this sample, there is no reinforcement to start with. Had the fillet been convex, the reinforcement may have been removed if required. In no case, however, must the fillet itself be ground away as this simply eliminates the connection. In the case of butt welds on the other hand, the weld itself lies internally with respect to the parts joined. The reinforcement may, therefore, be either ground off flush or left on as required.

MR. BENNET: I have heard it said that a welded joint is a stronger piece of fabrication than the plate itself. Is it possible, Mr. Reisser, to make a joint actually stronger than the plate or plates with which it is joined?

MR. REISSER: Although I know that this claim is frequently made and often by representatives of electrode manufacturers, that—to be quite frank—depends entirely on the type of load to which the joint is subjected and also the type of electrode used. Provided the electrode deposits weld metal of mechanical properties equal to those of the plate, the joint is 100% strong under static loading. Failure invariably takes place outside the weld as the latter's yield point is slightly higher than that of the parent metal. If this inequality is a fault—it is a good fault since it means that the weld still remains elastic when the plates are yielding. Under fatigue loading, however, a butt weld does not develop the full strength of the plate. Dr. Dorey, Chief Engineer of Lloyds Register of Shipping, in his paper on "Welded Pressure Vessels," read to the Institution of Civil Engineers last spring, stated that his wide experience in the testing of welded joints made on boiler quality steel leads him to regard the figure of ± 11 tons per sq. in. as a good average value for the Wohler fatigue endurance limit of a butt weld.

For mild steel, it is ± 12 to ± 13 tons per sq. in. There is also the question of corrosion. This depends entirely on the electrode used. In the case of bare wire—which is still sometimes used—one can

not help large inclusions of oxides and nitrides and the corrosion of such a weld is much lower than that of the steel. With covered electrodes, on the other hand, the weld usually goes last and corrosion starts just outside it. The experience of Lloyds and The British Corporation leads them to regard such welds as having a corrosion resistance at least as good as that of the plates themselves.

MR. BENNET : Taking that then, suppose, experimentally, you had a beam supported at both ends and you cut it through the middle ; you then weld that cut and, still with the beam supported at both ends, you depress that beam until something gives. Would the structure of the beam give, or would the weld give first ?

MR. REISSER : This would depend on the position of the weld. If it were placed at the point of maximum stress—say at the centre of a freely supported beam under a concentrated load or over the support in a cantilever—then the weld would always be stressed most and, with an increase of load, the limit would probably be reached there first. If, on the other hand, it were possible to subject the cantilever or the beam to a uniform bending moment, failure would tend to take place outside the weld on account of its slightly higher yield point. In practice one would not normally place the weld at the point of maximum stress—thus providing an extra factor of safety for the joint. In fact, in Italy where, owing to a lack of raw materials, most of the steel has to be imported, and the saving in weight is, therefore, a primary consideration, the end-to-end butt welding of beams is quite common practice. They utilise the principle of continuity in both directions, the longitudinal beams being often threaded through double joist battened stanchions, and butt welded to each other throughout their length. The butt welds are usually placed at a short distance from the stanchions close to the points of contraflexure so that the joints are subjected only to a very slight bending stress.

MR. LEE : Does welding not set up a terrific local stress, and if so, how is it overcome ?

MR. REISSER : I take it you are referring to the residual stress ? The whole of this question is, as yet, a very debatable one. Far be it from me to say that you have no stress set up during welding, but it must be remembered that you also have it in any casting. And just as a casting tends to distort if machined while green, so there is the same tendency in a welded fabrication whose internal equilibrium is disturbed by the removal of the skin in machining it. When working to a tolerance of 1 thou., or something of that order, the resulting movement would probably be noticed and for such cases it would probably be advisable to anneal the work after welding. At the same time, everything seems to imply that the longer the time elapses since the welding was done—the less the stress becomes. What is more, the application of external loading also

appears to decrease the residual stress, so that when the load is removed and the internal stress re-measured—its magnitude is usually found to have decreased. A theory put forward in explanation is that the application of external loading has the effect of superimposing a stress on that already present internally. If the load is sufficient to raise the total stress to the yield point of the material, a slip takes place and the internal stress is decreased if not entirely eliminated. This is probably the object of the so-called method of mechanical stress relieving often resorted to in America in the case of welded pipes, cylinders and so on.

MR. BARCLAY: In my experience of welding one of the greatest difficulties is in the kinds of bright steel or black bars used nowadays, the welding of the polished bar compared with the black bar. There is greater difficulty in getting the weld to stand the strain than on the black bar. Is there any method, say an annealing process? Can you give any idea as to why that should be?

MR. REISSER: What exactly is the difference in strength?

MR. BARCLAY: Say, for instance, $\frac{3}{4}$ in. polished steel bar to about 60 ft., we get it in 16 ft. lengths and weld them together, and everytime it has been used it has broken at the welds. If we take the ordinary black $\frac{3}{4}$ in. round bar we never get this trouble, welding the same way.

MR. REISSER: In cold drawing a bar you get the same effect as in wire drawing: the tensile strength is increased at the expense of the ductility. That is why it is possible to twist without fracture an annealed wire many times more than one which has been drawn. The latter, on the other hand, has a much greater tensile strength due to work hardening. If only the bright bar is cold drawn, it may have something to do with that. The welding heat would have the effect of annealing the bar adjoining the weld and thus locally eliminate the extra strength due to work hardening. Even so, however, I would expect failure to occur not in the weld, but adjacent to it——always providing that the electrode used deposited weld metal of equal strength to that of the drawn bar.

MR. PEET: I could probably add a word there; motor car steering columns are made of bright drawn tube, being welded to a top piece of mild steel bar, and no trouble is experienced in welding the two parts together, so I cannot see the point in the difference bright and black bars would make.

MR. WILSON: Do you find that the vibration of fabricated structures is more or less than in cast iron structures?

MR. REISSER: That depends—do you mean of the same dimensions, similar design, and construction?

MR. WILSON: Yes.

MR. REISSER: Less, undoubtedly. You have, theoretically, less rigidity in cast iron, and the vibration would therefore be greater.

MR. WILSON: Have you found that to be the actual case?

MR. REISSER: No! I am only talking theoretically from figures. I have not come across any cases, where mild steel has been substituted for cast iron without a reduction in weight. Even there, though, I have not heard of any difficulties experienced.

MR. WILSON: In welding shop work we find there is a tremendous vibration given off, more so in welded bed plates than in cast iron ones. That is why I asked you that question. There is another point that struck me. In foundry practice there is a certain range of fusing temperatures which have a definite effect on the actual strength of the casting. When you are welding you have a machine which gives a certain current, and so forth, and you are melting a metal at no determined temperature (not that we know about anyway), because the machine varies from the time we get it in until we throw it out. Has that any effect on the strength of the structure?

MR. REISSER: With definite voltages and amperages you should get the same welding results, no matter what the condition or construction of the machine. I cannot agree with your point about temperature; the temperature is very definite. The *amount* of heat is very definite (the temperature does not matter so very much), and that is the greatest point we claim as against acetylene welding. It is determined not by the welder but by the manufacturers of the electrode. With every electrode you are using a definite arc voltage and if you increase your current the speed of welding also increases. In oxy-acetylene welding, the welder has his filler rod in one hand and his torch in the other. If the job gets too hot he can take his torch away from it and continue to deposit metal by applying it to the filler rod and vice versa, so that the control of the heat is entirely in the hands of the operator. In arc welding, on the other hand, it is not possible to apply heat to the job without welding nor yet deposit weld metal without applying the heat to the work as well as to the electrode. That, frankly, is possibly a weakness of the arc process, when you apply it to such materials as aluminium. You are doing quite nicely one minute and the next you have a hole. You have got to watch that and regulate your speed very closely as you can not take your heat away when you see it forming and put it back when necessary as in the case of gas welding.

MR. BURNS: Would the lecturer be good enough to give some of the advantages claimed for electrode welding as against oxy-acetylene, and an idea of relative costs?

MR. REISSER: I am afraid I have no knowledge of oxy-acetylene costs at all as it is entirely outside my province. That arc welding

costs do compare very favourably, however, is undoubtedly claimed and the very fact that it has replaced oxy-acetylene welding in the majority of large fabrications would appear to substantiate this claim. One of its greatest advantages is also the fact that the weld metal is of standard quality, whereas in the case of gas welding the quality is in the hands of the operators depending as it does both on the flame adjustment and the amount of heat put in. The flame may be neutral, oxydising or carburising and only the first will not effect the weld metal. The second will introduce oxides and the third carbon into the weld so that its properties will be affected in both these cases. The arbitrary heat control may result in burnt metal or, more likely, in a lack of fusion between the weld and the parent metal which would be due to the flame being played more on the filler rod than the sides of the plates. In arc welding the heat is generated at the poles between which the arc is struck and, since one of them consists of the work itself, this condition does not arise. As for burnt metal—it is entirely out of the question since the heat input and the metal deposition are automatically synchronised. Another advantage is the undoubtedly decreased distortion due to the fact that the heat is both more intensive and localised—there is no question of that whatsoever.

MR. BRUNTON: Suppose I were the manager of a small shop and thought, well, I have to do something about this welding business, and decided to train one or two of my young men in welding. What does Mr. Reisser suggest that I do to see that these men are properly trained? I want to make sure that they are going to get a sound training, and perhaps I am quite prepared to put them in the hands of a good firm of welding experts and even pay for tuition. Does his firm, for instance, train operatives for a certain period in the use of their welding products, so that an executive without a great deal of trouble may be sure that he is going to get his men properly trained?

MR. REISSER: As regards training, most electrode manufacturing firms have a school attached to them and they take in pupils. The school is a part of the service they give, not done merely for advertisement. Also, we take people from outside if we have room in the school. We have only 12 machines and we insist that every man has a machine to himself. He has got to work all the time he is there. The training is very short, the course is only a fortnight, and there are only five days in the working week. We cannot make a welder in ten days, but each man when he leaves has been shown every type of weld, he has been shown how to do it, has had some practice under guidance, and he is what we term an improver. He has got to go outside and practise for himself unless he wants to stay for a longer period. They usually go out as improvers on unimportant work, where welding is merely joining the parts. How

long it will take him to become a welder depends on the man. I know one case where a man who had never seen an electrode in his life was a really good welder at the end of that fortnight, but that is very rare, and it usually takes three to six months after that. The British Oxygen Co. likewise have a school for gas welding, but I think their course is six months. There is a lot more art in oxy-acetylene than in electric welding. We say a man is not a welder in a fortnight, but he knows enough to go out and practise on unimportant work. If I, therefore, were in the position you mention and the shop was a general engineering shop dealing with all sorts of metals, I think I should have the young men trained in both arc and gas welding—because in a number of instances I would prefer to use the latter process. For instance, I have already mentioned the welding of aluminium. You can make electrodes for it, and I could show you some perfect samples, but, as yet, probably only one welder out of 100 could reproduce them every time.

Mr. Wilson : We have a number of jobs we make of Scotch iron and different qualities of iron, e.g., Armco & Terrelco iron, and we have always found corrosion keenest at the welded joint. We use mild steel coated rods. Can you give me a suggestion of the best type of electrodes to use for resisting corrosion when joining iron plates ?

Mr. Reisser : What exactly are the plates ? Do you mean cast iron ?

Mr. Wilson : The ordinary wrought iron plates that are sold at the present time.

Mr. Reisser : That is about 24-26% tensile. For purely corrosion purposes in welded work high nickel-chrome steel and electrodes are usually used. Yours is a difficult question and one which I would not like to answer off hand. Ordinary mild steel electrodes are normally used, but I do not know whether their corrosion resisting property would be as high as that of good quality wrought iron. Do you have any difficulty with the laminations ?

Mr. Wilson : We do range boiler work for house boilers. The welds always give first, due to corrosion.

Mr. Reisser : That type of iron is usually laminated and it depends which way you make the connection. If you weld the plate so that all the laminations are connected that is all right. But usually you weld to the top lamination only and there is a tendency for the weld to pull out. As regards the electrodes I would recommend for that work, I would not like to say off hand, but I could drop you a line as soon as I get back, if you will let me have your address. We have people who specialise in that kind of problem and I would certainly let you have the electrodes we recommend for it.

Mr. Allen : With regard to these welded gear wheels shown, Mr. Reisser, you said the rim of the wheel was made of a harder

material. Can you build up a wheel with say $3\frac{1}{2}\%$ nickel steel rim and ordinary mild steel centre?

MR. REISSER: That is a question I have been expecting, but, unfortunately, as I received that photograph by post, I do not know what material was used, or how it was done. As regards your own question, it is not possible for me to answer it until you tell me what the nickel steel is. The $3\frac{1}{2}\%$ is all right so long as your carbon is very low. With an increase in carbon content, however, you have an ever increasing tendency to get a hard and brittle junction.

MR. ALLEN: Take a $1\frac{1}{2}\%$ nickel chrome oil hardening steel! We make gears of that material entirely, but it is expensive. Can gears be built up with the rim of the high grade material and the body of the wheel with a lower grade material?

MR. REISSER: That is another question which is very difficult to answer. I could discuss the stainless steels fairly generally as most of the steels in that range pretty well fall into one or other definite type having definite welding characteristics. With other alloy steels, on the other hand, I would never give an answer unless I had the exact composition and heat treatment of the steel with, preferably a small sample of it. In such cases we are always prepared to carry out an experiment and would then let you have the results and our comments and recommendations. I have heard this same question asked at a lecture in London given by one of the best known men in the welding industry and it struck me then that the answer he gave—" Yes, you are apt to get some porosity but it is quite weldable "—was extremely dangerous on account of the tremendous variation of results which one gets with a variation in the carbon content. So that if you also would like to let me have your name and address together with the particulars of the steel and, preferably a sample—we will have it welded, test it and let you have the results together with our recommendations.

Discussion—Glasgow Section.

MR. G. M. BUCHANAN : As production engineers I think we are mostly interested in comparative costs, and I must say I am very disappointed indeed that Mr. Reisser decided not to give us anything at all of that nature, but simply to give us an elementary paper on welding. I hope that production engineers are not going to the managing director to ask him to change over to welding without knowing the costs. That is the impression, I think, that most of the people who do not know very much about it would get from what Mr. Reisser has said. He should have told us that it did not always pay to fabricate. Those examples which he has shown are the very best he could have shown, but we want to know comparative costs. Fabricated work would probably cost £35, £37, or £40 per ton, and we can buy castings at £20 to £22 per ton. Also take the older engineering firms who have stocks of patterns and who have not got rolling machines or cutting machines, surely cast iron in these particular cases is going to be more economical than mild steel fabricated?

Another aspect of which I have heard concerns mild steel gear cases. Is it not the case that the noise from these is much more than from cast steel? Recently I have had complaints of the noise from fabricated steel cases. On the other hand, I must congratulate Mr. Reisser on making out a very good case for welding. I am a member of the Welding Institute, and I know that welding does pay under certain circumstances, but I would not like anybody to go away from this meeting to-night under a misapprehension. When you are going to weld as a substitute for cast steel or cast iron, the first thing you must probe is the comparative cost. It is not always saving that matters, but in some cases you want that. This particularly applies to buffing machines made by people who have been manufacturing such machines for a number of years and they still make them of cast iron.

MR. REISSER : I thought something like that would come along and my answer is very simple. No actual cost figures have been given because I have yet to meet anyone who would be willing to give the production costs of his firm—as distinct from the prices quoted. I could tell you what welding should cost, but that is a very different thing from the prices which are often demanded. There is still a great deal of opposition to welding for reasons entirely non-technical and it frequently happens that, where alternative prices are asked for, the price for welding is very much higher in spite of the large saving in weight which usually results. I have

heard quotations of £45 and £50 per ton of structural steelwork and yet we are at this moment constructing a new single-storey factory with a covered area of 4½ acres and of an entirely welded construction which shows a distinct overall saving as compared with a similar riveted type of structure.

I have also shown many examples of the work of firms like, for example, Colvilles Construction Co. Ltd., who have taken up welding wholeheartedly and whose director, Mr. R. W. McBride, has definitely stated in his paper "New Power and Turbo-Blower House at Clyde Iron Works"—read before the Institution of Structural Engineers—that welding was cheaper than riveting. A considerable number of the slides likewise showed constructions and plant fabricated by firms by way of replacement or extension of their own works, and it is inconceivable that such work should have been done by welding if the price had been higher than that resulting from the use of other methods of construction.

Then again you saw a number of examples of heavy machine work done by Dorman Long & Co. Ltd. It was carried out by a department which has been specially started for this class of work—although most of the work in the constructional shops of this firm is still done by means of riveting. So that, although I am unfortunately not in a position to give you figures, surely these examples are a sufficient proof of the fact that the comparison of costs usually favours welding. At the same time, I entirely agree with your remarks as regards the use of cast iron. Welding, in my opinion, will never entirely replace it. It all depends on the particular machine part under consideration—whether the patterns are simple and also the number off required. So in the case of complicated components of which only one or two are to be made—I would recommend welding every time, but if the number is large and the patterns simple—it will probably pay to use cast iron.

Similarly with riveting. There are a number of cases where a flexible joint is essential to the design and riveting may be preferred for this reason. Thus to-day there is practically no ship that does not incorporate a considerable amount of welding, but certain parts are almost invariably riveted. As regards the question of firms possessing equipment for riveting and casting and the advisability of scrapping it on account of welding, my answer is definitely yes—if welding is the most suitable method of fabrication for their type of work. After all we once used wood for bridges, and have now changed over to steel so that the firms engaged on this work have had to change their equipment. Yet I have never heard this having been put forward as an argument against the use of steel. Also one must not compare the riveted and cast work of properly equipped shops with welding done in a hole and corner fashion—which is

still to be seen only too often—if a true picture of comparative quality and cost is to be obtained.

With respect to noise in connection with gear cases, I have had no personal experience, but have not heard of any complaints. Nevertheless I should imagine that this could easily occur if the weight was cut down to the absolute minimum required by considerations of strength only and all other factors neglected.

MR. W. P. KIRKWOOD : The point which struck me most forcibly in the paper was the emphasis which was put on the modulus of elasticity. I think that is a thing which is very often overlooked by the engineer and its importance is much greater to-day than it was twenty years ago, because we are demanding a higher standard of accuracy and more output from machines of any particular capacity and both of these points demand rigidity. We have been too apt to say we want that job rigid. We must make it of cast iron because it always seems rigid. Mild steel can be bent. Reverting to first principles we must be reminded that the modulus of elasticity of cast iron is definitely much lower than steel.

In regard to the actual use of welding as opposed to cast steel, I think there is a very very good case indeed. Those of us whose misfortune it is to have anything to do with cast steel in the machine shop will, I think, agree it is the one metal we would like to get rid of. You never know if it is a sound job until it is almost completely finished. We may spend a great deal of money on machining it and when we come to the last operation, we get a crack or blow hole in some vital part, and it has all to be scrapped. The steel foundry is very helpful when things can be welded, but this is not permissible in some cases because of subsequent distortion. On replacing cast iron, I do not think that welding is on such sure ground as has been indicated, and I think there are many places where cast iron can be used on account of its cheapness. We don't always want rigidity to the last degree and cast iron, in spite of improvements in welding technique, does lend itself to smooth finish, and that is quite an important point. Mr. Reisser did not say how we were to detect good welding and bad welding, other than by visual examination. Unfortunately, in spite of what has been said for welding to-night, there is a lot of bad welding, electrical welding, and acetylene welding. It is not confined to any one firm or district. I am afraid a lot of firms should be blacklisted. They cannot turn out good welding, and apparently have no form of supervision to see that welding produced by the company is up to standard. Fortunately, we have notable exceptions, and some are in this district. I do think in their own interests supporters of welding should try to get these people out of the welding business. It would have a tremendous effect, because one bad weld is enough to condemn the entire system to a firm if it happens in something

important, and I think that should be one of the strongest lines of attack on these firms who are turning out work which is not up to standard and whose work is ruining the good name of welding.

MR. REISSER: Taking the last part of your remarks first, I entirely agree that bad welding does a tremendous amount of harm. Welding is a new industry and there is still a shortage of really good labour, although this state of affairs is rapidly improving. At the same time it is interesting to note how strong even bad welding is. If you were to witness the testing of butt welded specimens in our welding school—specimens made by students with only four days' training—you would find that even the worst ones, full of slag inclusions, gas holes, etc., seldom break below a stress of 20 to 23 tons per square inch. As regards cast iron, you mentioned that it lends itself to a good finish, and I am not quite sure whether you mean good finish as cast or after machining? In any case, mild steel is pretty smooth, even as welded. Look at the examples on this table.

MR. KIRKWOOD: It was rounded corners and so forth.

MR. REISSER: As regards shapes, most work is nowadays cut by gas and this process had reached such a high level of perfection that any shape may be obtained and the finish compares very favourably with machining. For example, I saw to-day a crank of an engine which had been cut from 6 in. slabs. It looked as though it had been machined, and if this can be done on 6 in. material, it can be done on thinner plates even easier. So that I do not think that the finish and shape is an argument for cast iron as against mild steel.

Your other point was that of inspection. There are means of testing bad welding, other than visual inspections, such as the X-ray method which is specified by Lloyd's for certain classes of pressure vessels. It does not, however, lend itself to all classes of work for economic and practical reasons. Nor is it, in my opinion, necessary since the quality of the weld can always be judged by visual inspection. It merely means that in important multiple run welds each run should be inspected separately. One glance will show the inspector whether it is good or bad and, with proper organisation, the work is not hampered by this procedure. Single runs on the other hand can be inspected on completion of the job. At the Institute of Welding dinner held in London last autumn, Mr. Leslie Burgin, the then Minister of Transport, said that the best way of answering a question was by asking another one. So I will put this theory to the test. If you cannot tell a bad weld from a good one, how did you know the weld was bad?

MR. KIRKWOOD: Because we could break it, the adhesion was poor.

MR. REISSER: If by adhesion you mean a complete lack of fusion between the weld and the parent metal, this is a state of affairs almost impossible in arc welding with good covered electrodes. The reason for this is that the heat in arc welding is generated at the poles, one of which is the work itself. In the D.C. welding the distribution of heat as between poles is not uniform, some two-thirds of the total heat being generated at the positive and the remainder at the negative pole. In the case of A.C. welding, there are no positive or negative poles, and the heat is generated equally at the work and the electrode tip. You will note that in each case the work itself is automatically liquified and fusion must, therefore, result—always providing that the current strength is correct, and the metal coming from the electrode is deposited there.

The first condition is obtained by means of the regulator provided on every machine, and the second forms the function of the electrode coating. This latter should stabilise the arc and, by falling on the plate first, should wash away all traces of the oxide film which may be formed on the plate, thus ensuring good fusion. At the same time it provides protection from the atmospheric attack for the weld metal during its passage from the electrode to the work, and ensures its quality by this control of oxide and nitride inclusions. On the other hand, in welding with bare wire or lightly coated inferior electrodes, this protection is absent and the weld metal is poor metallurgically. Furthermore, the arc is extremely unsteady and the globules frequently fall outside it on to unfused plate and often on top of the oxide film which is thus trapped between the weld and plate. In such cases lack of fusion undoubtedly often results. Similarly in oxy-welding, by playing the flame only on the tip of the filler rod, the latter only may be melted and the weld metal will fall on a cold plate with similar consequences. But in arc welding with good electrodes this state of affairs does not occur.

MR. BENTLEY: I was struck by the emphasis made regarding the relative modulae of elasticity of cast iron and mild steel. As the tensile strength and the modulus of these two materials vary in the same proportion, naturally the deflection under stress will be the same. Up to a few years ago I was connected with the electrical industry, and during the period in which I was engaged in this work, the progress in the change from cast iron to welded fabricated mild steel for electric motor yokes and stators was going on. It was found that this method of manufacture was cheaper, quite apart from the cost of patterns. The extensive storage capacity for patterns was avoided and the progress of manufacture was independent of deliveries. One thing was experienced; it was necessary to pay more attention to the relative supports of the yokes and bearings—i.e., relative deflection between the yoke and rotor had to be

reduced to a minimum. Some firms had some costly experience before fully realising this fact.

The tables shown by the author of the paper under discussion did not give any indication of the current values for the various electrodes. It has been emphasised here in this room times without number, that successful welding demands going about it in a methodical way. This is done by a proper layout giving to the welder particulars of the current, size of electrode, speed and length of run for a given weld.

I also disagree with the author's statement that with the frames shown on the screen there is only required a light weld due to the fact that the members are mainly under compression. Should not the weld be of a section so as to be stressed (per sq. in.) at the same value as the other portions of the structure ?

Mr. Reisser : With regard to the modulus of elasticity and equal strength, I am afraid I cannot agree with you. My statement applies only to equal weights and, in this case, since the modulus of elasticity and tensile strength of mild steel are greater than those of cast iron, the deflection of a mild steel structure must be less and its strength greater. Another point in this connection is the difference in the elastic limits of the material. If you look at the stress-strain curves for mild steel and cast iron you will find that the elastic limit for the former is considerably higher than for the latter. Since all design formulae are based on Hook's law—i.e., presuppose that the material behaves elastically, the working stress used for cast iron must be less than that for steel and the design strength requirements for cast iron will, therefore, result in larger scantlings and thus greater weight. As regards your experience in the electrical industry—was it recent ?

Mr. Bentley : Not many years ago.

Mr. Reisser : Then I would again emphasize that the application of welding to the engineering industry is a very recent development and even a few years make a relatively very long period. In common with all new developments it has the usual problems which must be solved by experience. There are the questions of personnel, supervision, distortion and, last but not least, design—since it is no use taking a riveted design and replacing the rivets by welding if one wants to benefit by the adoption of the process. Experience may, in some cases, prove costly, but the very fact that most of the large electrical firms have taken up welding on a large scale is, I think, sufficient answer in itself.

Mr. Bentley : There is one other point in which I am inclined to disagree with the speaker. He said that some of these frames only required a light weld because the stress was of no importance. I am rather inclined to disagree with that. If you made the frame

of the right thickness, the welding must be of the same section and material as the frame, I think that is ordinary mechanics.

MR. REISSER : I am afraid I cannot agree and will give you as an example the figures for an actual design. It is from structural work, but will serve equally well to illustrate the point. A stanchion over carrying a load of 55 tons had to be supported centrally on a plate girder of 30 ft span. The necessary section would, therefore, consist of a 36 in. × $\frac{1}{2}$in. web plate and 9 in. × $1\frac{5}{8}$ in. flange plates. The flanges would then be stressed up to nearly 8 tons per sq. in. near the centre of the span and the shear of $27\frac{1}{2}$ tons due to the central point load would be constant throughout the length and change sign under the stanchion over. Using the usual formula for the horizontal shear to be transmitted by the welding—i.e., $\frac{12\ A\ \ y\ S}{I}$, we find that the welds will have to carry 7.43 tons per linear foot of girder. By using $\frac{1}{4}$ in. intermittent fillet of 6 in. weld — 6 in. miss on each side of the weld and allowing a safe stress of 5 tons per sq. in. on the throat area as per B.S.S. 538-1934, the permissible horizontal shear per foot is 10.8 and this welding will, therefore, be sufficient. In practice the flange plates would probably consist of several plates, and the same amount of welding used between each pair.

MR. MCFARLANE : There is one question I would like to ask the lecturer—namely, in machinery, especially in machine tools, how about the stresses which are bound to be set up during the welding operation ? What will be the after effect on the machine tool itself ? Are special steps taken to relieve those stresses by any normalising process ? Some of the structures, such as beds, might be a considerable weight, and it would be extremely difficult to handle them in the furnace.

There was another point (apart from the question of elasticity, which has been mentioned, and I would agree perfectly there); I may have mistaken the lecturer, but I think he went on to say that the yield did not matter. It was actually an advantage in the case of mild steel for the material to be made to yield, that is, at a point beyond the elastic limit, but in the case of a machine tool, what effect would such a yield have on accuracy ?

To get away from machine tools, in my own particular work we have purposely kept away from materials which are apt to yield under a blow and would prefer that the part should break and thereby declare the fault after falling or being mishandled rather than make the part, such as a part of a gauge, of a material which might yield and permit the error to remain unnoticed. Well, I feel the same about any part of a machine tool, especially an accurate part such as the slideways and if they were unduly stressed beyond the

elastic limit, that would be a very bad feature unless the designer were to allow a very large factor of safety.

MR. REISSER: The question regarding the residual stress is one that I have been expecting and one which I should have incorporated in the lecture. Internal stresses are set up, but they appear to be similar to those set up by the cooling in castings, which, when machined green, are also liable to distort. Conditions in welding are in this respect similar and numerous experiments have shown that internal stresses may remain after the work is completed. There is also evidence, however, that these stresses just as in castings—tend to work themselves out.

If the welds are small and you are dealing with thick plates, the material will probably be strong enough to resist the internal stress and no visible distortion will occur. I mentioned this in connection with structural work at this same lecture which I gave to another section of your Institution and was promptly told by the questioner that he had found a distortion of several thous. which was most important. In structural work one usually works to tolerances of the order of $^1/_{16}$ in. and three thous. would not matter in the least, but if you are going to machine the job and are working to very fine limits—it is advisable to relieve the stress by normalising or annealing prior to machining. I understand that this is also frequently done in the case of castings. With regard to the question of yield, were you thinking of repairing a broken tool or fabricating a machine?

MR. MCFARLANE: I was thinking of machine tools made of fabricated parts—you made a general remark that the yield is not important.

MR. REISSER: That was in connection with machine components. I was referring to the higher yield—and, therefore, elastic limit—of steel which allows the use of a lower factor of safety, and results in a saving in weight. In machine design, however, the requirements of rigidity often necessitate the use of considerably heavier sections than those required from considerations of strength alone. The saving, therefore, which might have been effected on account of the lower permissible factor of safety is thus offset and it was in this sense that I mentioned the yield being unimportant. In the process of fabrication, however, it is of the greatest importance. Shrinkage stresses of unknown magnitude are set up and concentrations of stress may result in cracks in the use of a brittle material. In castings this is counteracted by avoiding sudden changes of area and sharp corners as much as possible—a procedure usually resulting in heavier weight than necessary. In welding, a ductile material is used, and the parts which may become thus overstressed, will yield and result in a redistribution of stress without fracture.

MR. ARCHDALE : My firm is one of the few firms in the country which have used welding on small parts and our experience has been that the cost is somewhat high, but the convenience is very often great indeed and we have used weldings mainly for the pieces of special purpose machines on which we did not want to go to the cost of making patterns. As far as the distortion of the small parts is concerned for machining, we have found that to be rare, but have had extreme difficulty in some cases. The distortion has been very heavy and we have never used weldings for specially accurate combinations. Parts are welded in small fixtures, not very costly, then we rough machine and anneal. It is usually annealed once or twice if the job is to be held to a tolerance of .001 in. We have found some difficulty with noise. In some cases we may not have been very careful with the design of our structure, but we did not do our own welding. It was done by the British Thomson Houston Co. at Rugby. They have done some remarkable jobs for us from the speed point of view. They have done jobs in a few days when the designs and special drawings would have taken us weeks. It is very convenient in such cases. As far as the future of welded parts for machine tools is concerned, I am not very optimistic owing to its cost. Many of our concerns have tried to use all welded structures for their standard machines and I think when it comes to a question of fabrication in series the cost would be very high compared with the cost of a pattern. I should rather like to hear Mr. Reisser's experience on what is being done in the United States as regard the fabricated parts for machine tools.

MR. REISSER : Regarding the first part of your remarks, it seems to me that your firm is using welding in the right way. I already mentioned that, in my opinion, it will never entirely displace castings and should only be used where it is justified by cost. This entirely depends on the particular job in question.

As regards speed, I must thank you for mentioning this most important point, which I accidentally omitted. Very frequently welding more than pays in spite of a higher price because you can get it done there and then, whereas you might have to wait weeks for castings and thereby lose orders. A very good example of such a case was brought to my notice a short while ago. A certain large firm had a contract for the works of another engineering firm and the job necessitated the use of a number of simple castings, which could not be obtained under some fifteen weeks delivery. Fortunately, however, the customer had a maintenance department well versed in arc welding and the situation was saved by his offer to fabricate the necessary parts. This resulted in the whole of the contractor's drawing office taking a course on welded structural design and a number of their standard drawings have been subsequently modified for welding.

As regard distortion, I have already mentioned that it can usually be entirely overcome by correct procedure which is a sequel to experience. A practical example of this occured recently in one of the railway workshops in this country. It concerned the welding of a built up H section for a solebar and, due to relatively heavy welding, the flanges curved downwards. The foreman quite rightly decided that a preliminary dishing upwards would cure the trouble, but omitted to explain his theory to the welder. The latter promptly placed the plate with the edges pointing downwards and the flanges completely folded round the web. But it proved the foreman's theory and it has become standard practice in these shops with the result that the solebars came out without any distortion whatever. I understand that the same job is being done in Germany in yet another way. While the welding is proceeding on the web side of the flange plates, heat is being applied to the underside by means of a blow pipe and the finished product is free from distortion.

With regard to American practice, Mr. Chapman, whom I mentioned previously and who is very well known in the American welding industry, definitely states in one of his papers that normalising is resorted to in his works. I also understand from Dr. Paterson that when the machine part is too big to go into the furnace, it is quited common American practice to build a temporary furnace, around the part and that the cost of this procedure is not unduly expensive.

What you said about noise is quite possible, but I have had no personal experience of it.

Mr. Randle: It is remarkable to me how free the alternative processes, which welding has superseded, have been from failures in the past. This applies not so much to castings as to forgings. I have replaced a lot of forgings. Marine engineers have to get a rather fine finish. If these parts are made of forgings there is an immense amount of machining on them, especially on the bosses, but if one makes the parts by simply welding plain bosses on to flat material, there is plenty of saving by using weldings instead of forgings. The game is beset with difficulties. I'll tell you the kind of diehard experience we have had. I had one of these fabrications made, using mild steel and the results were remarkably good, only a few "thous" undersize. I had one die-hard inspector who discovered that one of these plates was a few "thous" less, and he turned the job down. It was a piece I could not easily replace, and when I asked him why he had rejected it, he said, "When I see on a drawing 1 in., I expect 1¼ in. That is one case where I definitely found quite a saving by welding compared with forgings.

The last speaker mentioned about weldings coming out more costly, and I have had previous experience and found that difficulty.

I think, Mr. Reisser, that where weldings are comparatively small, the cost per lb. is prohibitive, and I have found it best, before deciding whether we would fabricate or not, to obtain certain figures, and then decided to leave them as castings.

The speaker said that overhead and vertical welding were a little more expensive than horizontal welding, but this does not bear out our experience, and we have to decide whether to weld a structure on the ship or do it in the shop and then put it in the ship. If we run out the actual cost of vertical welding generally against horizontal welding, we find that it is somewhere in the order of four to five. I would be glad to know your opinion on that.

The other thing I would like to have information on is just this. I think most people here who know a little about welding find that Admiralty overseers don't want to use a gauge bigger than 10 for rods in the use of welding, but we who are welding daily know that this custom is not necessary. I was rather astonished to find the other day that one overseer decided that they still wanted to stick to this. Is the speaker aware whether any exception has been granted on the part of the Admiralty ?

I was delighted to hear the speaker reinforce this statement that good welding looks well. I had occasion to insist some time ago in a new shop that the finish of the welding must be improved. I have with me at the moment a resident French inspector and he, on studying our work said that good looking welding is good, and I think that is the only way to ensure that one is getting good welding.

Mr. Reisser : With regard to forgings, I am not quite sure whether you are for or against. If you say that you have heard of no failures in forgings, I on the other hand have heard of quite a number—mostly from engineer surveyors, many of whom have been through our welding school.

You mention that welding does not pay on small work and I am inclined to agree. I note that your method of ascertaining whether it should be applied to any specific job is to find out the amount of welding per lb., and that above a certain figure you do not use it. I particularly note that you do not mention what that figure is and, as I have already mentioned, this omission is quite in accordance with my former experience.

I have no figures for machine tool work, but a certain German expert who designs and builds railway bridges and, furthermore, makes his own steel—and should, therefore, be in a position to know—states that on plate girder work the saving in weight is in the order of 18%. The price per ton, is however, slightly higher and the overall saving is thus reduced to some 12%. He further

states that this percentage is gradually increasing with the increase in experience of welded work.

Vertical and overhead welding is, in my opinion, more expensive than horizontal because the more tiring position in which the operator has to work results in a smaller output per day and, therefore, greater cost per ft. run. If the amount of such welding is small, there may be no difference whatsoever, but if the welder is kept all day on either horizontal or say vertical welding—it is sufficiently marked. So, for example, on a certain large structural job of which I had charge as regards the welding, a good operator used to produce 60 to 80 ft. of a single run fillet per eight and a half hour day using No. 8 gauge electrodes. The corresponding figures for horizontal work were 80 to 100 ft., and we even actually had 130 ft. using No. 6 gauge. It must, however, be borne in mind that these figures apply to welding of a continuous nature. If the work consists of short runs and the operator has to do much shifting from place to place—they would be considerably less, so that one must remember that output figures depend entirely on the type of work.

As regards the maximum gauge allowed by the Admiralty, I rather think it is No. 8, and it is because of such requirements that our data cards show 1 in. welds made with eight-gauge rods which requires 17 runs. Personally, I think that the gauge should vary with the thickness. There is a school of thought which states that the superimposing of small runs normalises the preceding ones thus improving the metallurgical quality of the weld metal and increasing the ductility. To a large extent this undoubtedly is the case, but I look upon it from the purely engineering point of view, and if by using larger gauges I can still get the specified tensile and elongation—that is good enough for me.

With respect to finish, I was not merely referring to the neatness of appearance, but also took into account the profile of the weld and shape of the joint. You may have a good neat finish, but the weld metal may be overlapping or, alternatively, the plates may be badly undercut—both the latter cases being indicative of wrong current conditions so that if you take the word " appearance " in this broader sense, then it certainly is a means of judging the quality of the welding.

Mr. Lang (Section President, in the Chair) : It is my privilege to thank Mr. Reisser for coming and giving us such a very interesting lecture. I would like to congratulate him particularly on the way he has handled the discussion.

Discussion—London Section.

MR. MUNCASTER: The cost of the electrodes is a tremendous thing against the use of it. If you are running on blocks about 1 in. thick—and we like to do that to get a nice rounded joint—well, that fairly swallows up the electrodes and we often feel inclined to use bare wire where we can. We should like to know when it is going to be a bit cheaper.

Anyway, there is another thing the welding does. It sets up a lot of stresses in the metal, and we find it necessary, as we build pieces weighing two tons sometimes, or perhaps the machine presses three or four pieces, and we find that they get twisted or we are afraid of the welding going, or anything like that, then, as I say, we find it necessary to stress, and that means we have to get them in a furnace, and it is often difficult to find a furnace that will take them, especially if it is a big piece. However, up to now we have managed to get pieces stress-relieved say, 16 sq. ft., that is 4 ft. long by 4 ft. wide, and we have to leave them in the furnace about an hour for every inch thickness of plate, and the time you leave them in the furnace depends on the thickness of the thickest part of the plate in your machine. They run them up to about 1,200°F., which we feel sure relieves all the stress in them, otherwise we find that when we start to machine by the time we have machined a second part the first part has gone out of line, but now we have started to stress we have got over that difficulty to a very great extent.

THE LECTURER: As regards the cost of electrodes, that depends upon quite a number of things. If more welding was used I have no doubt the cost would come down. As regards the distortion that you get, that is proportionate always to the amount or volume of the welding that you put in, and that is one of the many reasons why I always advocate that it is better to put one cubic inch more of welding than is absolutely necessary. Could you not do this? It would save your distortion and your costs. Alternatively, what size of electrodes do your works use?

MR. MUNCASTER: About eight gauge.

THE LECTURER: Well now, you are using eight gauge electrodes for 1 in. thickness of plate. The price of electrodes to begin with is high, because the smaller the gauge the dearer it is. There are more to the lb. if you like. I would suggest you use ¼ in. electrodes, and the cost will be much cheaper. I think it is always advisable to proportion the gauge or gauge-size to the thickness of plate that you are working on, as in your case I should say ¼ in. to ⅜ in. As

regards stress-relieving afterwards, that depends on your work. If you can get your job done without distortion in the first place it will not distort afterwards, and there is no need to stress-relieve unless you have to machine after welding, in which case frequently by taking off the top skin you may then get slight distortion.

Mr. Stoessel: I have one question I would like to ask the speaker. He states that welding of iron and steel plate is satisfactory with regard to cast iron, while we ourselves prefer to bolt and rivet, because it is likely to preserve in fabrication much more readily, and I would like some discussion on that to find out whether I am right or wrong. Then I have another point with regard to stress relieving, and that is that we ourselves have found it necessary to make some frames weighing up to five tons or so, and have found that when we have sections to plate 2½ in. thick, and try to make a butt section to form a rigid section of a press, or something like that, that there is a tendency for the plates to crack because the plates themselves cannot take up the stress by deflection, consequently we must stress-relieve in that case. Now, I would like the speaker's comments on this.

The Lecturer: I am inclined to agree with you there. If I dared to advocate the complete elimination of castings, I would. I think that both castings, riveting and bolting will always have their application and will never be superseded. I think you certainly have a big advantage in using welded construction, but where you get fabrication like that I think I would be inclined to agree with you. It depends upon the particular conditions, and so on; by increasing the thickness you probably get over it. There are definitely cases where that is the only way, although there are others where you have a very simple cast and you use designs for them, and would never be able to make a welded structure at the same price.

Now, as regards stress-relieving, I would suggest that most of that cracking is probably again due to procedure. You can make any electrode crack if you try to, by using very thick plates and a very small run. Another thing you have to remember is that you must put down a plate-prop, and if you are welding, then the welded material must stretch under the cooling presses. Well now, cracking is proportionate to the thickness of the plate, and if you have a very small area cracking will take place, and another point is that cracking takes place in the cooling, not after your welding, so that I do not think stress-relieving will help to any great extent. If a crack is there, it is there at first; it does not occur afterwards. Hair cracks that you cannot see will show up afterwards, but they are there to begin with, and stress-relieving will not remove them.

Mr. Nolan: Twenty years ago I joined the Admiralty, and at that time they were using welding to a very large extent, they

welded from $^{1}/_{64}$ in. plate up to 2 in. I was manager of the department at that time, and we had there a machine which operated at the rate of 300 rivets an hour, and that I think has been working for a number of years and is quite satisfactory. I am afraid I am going to have enemies. The lecturer has spoken about different electrodes in different classes of work. In those days in Devonport we used electrodes that cost us a terrific pile of money, but if the lecturer is ever down that way and takes a walk through any of the shops he will see a boy sitting spinning his own electrodes in the dockyard there. I am now actually in civil engineering, general, civil, structural, and mechanical, and if I do happen to want anything in the nature of an electrode for a welded piece I know before I start that it is going to be thrown aside, but in doing electric welding we now have a great amount of information.

Then again, when I went to Scotland I was amazed at the lack of knowledge about electric welding ; you might fancy it was some recent discovery. I was one of the first to weld a bridge. All the rivets in this particular bridge were welded and the structures were tested to 300 lbs. a square inch, and that has stood up remarkably well to the welding in that case. I took at that time some notes of electric welding and I find that for work from $\frac{1}{8}$ in. up to $\frac{1}{4}$ in. were paying at the rates of 2d. per foot and $1\frac{1}{4}$d. per lb. for electrodes. They varied from $3\frac{1}{2}$d. for $^{3}/_{16}$, and so on, up to 2s. 6d. for three-quarter welds, and I would like some information as to whether these prices that I have here at the moment seem at the present date to be in conformity with the rates prevailing now as regards fabricated machinery. Personally, I cannot see any machine that cannot be fabricated, from 500 ton presses down to the ordinary hand-press, and I cannot see one particular case where fabricated machinery cannot replace castings.

As regards relieving stress. You may know the type of ironing beds which have recently been installed in the Savoy Hotel, London, and of which there are several all over the country. They are about 30 or 40 in. in diameter, varying according to the size of laundry machine you require, and every one of them have stood up and replaced what were previously castings, and as I say, I cannot see one particular case in engineering generally—and I might say I have a fairly good experience—I cannot see one case in which electric welding cannot be applied. I would like to know how the rates would compare at the present time with the figures I have collected over a number of years.

As regards stress-relieving, that is one of the things which I was recently discussing with a Professor of Glasgow University. I had a base for a machine, and the thing had buckled in the bottom to an extent of about 1 in. It was 3 ft. diameter, barred with a very heavy weld, and to relieve stress in that I waited until 5-0 o'clock and I

got a man with a dolly and carried out what you now know as "spinning." In other cases where furnaces were to hand we had to relieve the stress, and when the particular article came out of the furnace we found the stresses were entirely relieved. That may help people who have furnaces and who may be able to furnace articles which they have fabricated, and as I say in regard to hydraulic machines and in hydraulic vessels. I remember, as I say, eighteen years ago the vessels going to sea carrying tanks all electrically welded, and I may say I take off my hat to the Admiralty when it comes to a question of deftness as regards welding.

THE LECTURER: There are one or two things which you have mentioned that I would like to comment upon, the Admiralty to begin with. Have you seen the Admiralty Specifications for welding? There is not one. They are very progressive let me say, but they are very particular as to the electrodes they use as well. Now the Dockyard electrodes I am very well acquainted with, but I think you will find they are only used on secondary structures. I have two men at the present time from there, who have brought with them three electrodes, one of which is not the ordinary Dockyard rod, but one for bronze welding. Well now, you can fabricate your own electrodes, all their coating consists of is a certain kind of wire, but it does not improve the quality of your material. You will get easier welding and better patterns, and although perhaps in machinery it does not matter, because rigidity is the main thing, when you come to structures materials which are not ductile will crack at that point and you will get progressive failure, and that is why continued and good quality is so important.

Usually it is quite easy to ascertain the average distribution of stress, but to get the actual stress on any point is a different thing. You get tremendous forces six, seven, and ten times as great as the average stress.

Now, I think you also mentioned about welding in Scotland. Well, I do not know that I would say Scotland is very far behind us. Have a look at the Corbell Construction Company's work. I should rank Corbells among the foremost people in this country for welding; they have a shop laid out entirely for it. Mr. MacBride, the Chief Engineer, told me personally that for the last year he has not bought a single rivet, and yet at the same time, when I suggested that he might do some jobs, he said that he was full up for the next few months—and that is all welded work. As regards there still being people who do not know about welding, well, I would suggest that is their own fault. All you have have to do is to ask.

Well now, about the presssing, you have raised a question that is extremely difficult to answer. I can tell you what the prices ought to be, but that is a very different thing. I have come up against cases of structural steelwork, for example, where an alternative

price had been asked for riveted and welded work, and although there was involved a large saving in weight in welded structure, the price was extraordinarily high, and I found that for the welded job the prices were £45 and £55 per ton as against £22 and £23 per ton riveted, and some of them have no compunction in telling you that even if the welding was cheaper than riveting they still would not want it. They had a very good riveting machine they did not want to scrap ! Now, if you can tell me the size of weld ?

Mr. Nolan : Say a 4 in.

The Lecturer : Well, I would rather take the example you had at the Hotel just now. You had a ½ in. weld and your time was twenty-two minutes for a man at the rate of 1s 6d. an hour. That is very reasonable for a welder at 8d. for a weld. Take labour charges only. You have 9d. you pay the man. Put on another 9d. for costs and charges, that is 1s. 6d.

Mr. Nolan : Well, now 1s. 4d., I think.

The Lecturer : I worked it out, and I find that the figures are extraordinary. As a matter of fact, I worked it out for one special electrode. It is as good a rod as you can get, best mild steel, and I find you can do those welds in many different ways. The price varies accordingly, but it varies mostly with the number of runs that you have, and it works out roughly to 4d. per ton, irrespective of the gauge. The price for shop work would work out to 1s. 8d., a four-run weld would come out at 1s. 4d., the bigger the gauge the cheaper. Also remember the times are included, change and fitting of electrodes and different sealing of the weld. To put down the weld does not take any time, and it does not vary, except by sections between different arcings, because usually the currents are high enough. What does take the time to remove is slag. With the better-quality rods you merely have to touch it and the slag in cooling peels itself off the weld entirely. In the Table I showed you, the times included the dip and change of electrodes and the dip and change of the weld. The probable time for de-slag is two or three times that of putting down the weld. It will cost you 4d. per ton as a fair figure.

Then the last point you mentioned here was spinning. Spinning is very good if you can do it when it is still hot. The weld, however, cools off very quickly, so that by the time you have finished one part another is just as bad.

Stress-relieving does take the stress away, but it does not alter distortion. It does not go back to the original because you have to take the stress out, usually in the distortion it is elastic. You can knock it back though in most cases, as you say. You can start welding on the one side, and when you see it coming over on this side, pull it back. You can also do it with jigs, provided you do

not start using too small a rod. Here again, the quality of the electrode comes in, and I do not think an inferior electrode would stand it, for you would have to have really good quality metal.

Mr. Nolan: Why give five runs in a 5 in. weld when two will do?

The Lecturer: There again you have difficulty in the welding when you start a big deposit. It depends upon the gauge that you use; if you have a very large gauge, that will show a tremendous proportion of the volume of welded metal and it can be done then, but if you start doing that with a small gauge of electrode the only way of doing it is by riveting. First of all, by excessive winding you are not keeping it steady and you are also probably leaving your slag inside it, and you will have a lot of slag. In fact, you will find yourself completely mixed up with slag. To give you an actual case. There was a certain job in a certain firm in this country where a fracture took place in service after a number of years. It was a welded job, and I was asked to look at it and give my reasons. Well now, I looked at it and it looked a perfect weld. I thought the design was not correct and I thought that probably was the reason; it would have been sufficient reason too. To make quite sure I had a few chats with the welders around about, and when the engineers and supervisors were not there one of them confided in me that it was a $\frac{3}{8}$ in. plate. Now, they used a 10-gauge rod and they made that on one rod. In this case the man just left all the slag inside, and when we cut it across the inside was filled with slag. Now you obviate that by using small rods and a number of them. The only way you get slag inside is by not chipping it. That is the reason why you could not do with heavier rods unless you make a quick change.

Mr. Banks: D.C. welding is not very widely used, and I would just like to have an opinion thereon.

The Lecturer: It is an important question, and I think it is a question of preference more than anything else. You will also find that it is a question of manufacture more than anything. D.C. welding is used less in our country to-day, although in some Continental countries, in similar circumstances, manufacturers of transformers will swear by D.C. and nothing else will do for them. Really, it can be done equally well on both and the results you get from the test point of view are equal in most cases, although there are rods which work better on D.C. and others which work better on A.C., there again it is a question of the electrode.

Now I will just give you one other instance, and that is the reason why, personally, if the electrode will work on both A.C. and D.C. I would prefer the A.C. plant, because it is cheaper. That is because of supply, and in the case of D.C. where you get definite poles, with current always in one direction and in cases using high

currents in the neighbourhood of 200 amperes, you may come across arcing. The weld metal will blow right away, there is no way of preventing it. There are ways of doing it, but you will find great difficulty on account of cracking and splintering. With A.C. we get no polarity, but the current alternates from positive to negative and vice versa, and the modern tendency being to use big gap electrodes for welded work on account of cost, we are using currents of 300 and 400 amperes. You start doing that with D.C. and you will find yourself in great difficulty with-out blow. For that reason I prefer A.C., but as you see it is a question of electrodes. Then there is the question of bare wire, personally, I would not call that an electrode for it will not work on A.C.

MR. BANKS : Is there any preference on cost ?

THE LECTURER : On cost ? Yes, definitely. As regards outlay on plant to begin with it is in favour of A.C. The transformer cost you about half the price of an ordinary generator and you have no maintenance at all. With generators you always get small adjustments to brushes and so on. As regards funning costs, there again I think you have the advantage, because no welder will switch off his machine although he may not be welding. Well now, during the time that welding is being done the cost will be the same, but in the case of a transformer, if you are lucky and are on the right supply, that only charges you for what you use and not for what they supply you, your costs will be much lower. On D.C. you pay for everything that is supplied to you ; you also pay for the time that the machine is running idle. At the same time you want to be careful before you instal A. C. because it upsets the power company's machines—it puts them out of balance unless you correct it by fitting a condenser, and unless you do that you will find that certain companies will not allow you to instal A.C. I know one gentle man who is not allowed to use it for that reason. We personally are luckier, we have an all-in-rate—we like transfomers !

MR. FINLAY : I would like to ask the lecturer what type of slides they use on their welding machine,—obviously mild steel will not run on mild steel,—and how they overcome that difficulty. There is another point that I would like to bring forward, and that is that where I am, at the Enfield Small Arms factory, we are doing a very successful job on a magazine, and we would like to have your opinion on automatic heat-control.

THE LECTURER : Now that first part of the question, with regard to welding surface. You can get a special electrode which is not in mild steel but a material very much harder. It will give you 600 amperes, and used to be used for monkeys and crossings. That is often done, and what has been done recently in the case of one of those bridges, is to deposit a layer—to build up a wall, as it were,

with one of those special layers, and you have got mild steel underneath but hard steel on top. This can be done,and you can do more than that actually, if you like to build up machine tools you can do that, but you must work high-speed steel. What you can do is to have a mild steel shank and high-speed steel on top.

The second part of the question was, I think, automatic control. The big advantage about this is that it gives you an extremely ductile weld, and what you loose in carbon you gain in strength from the nitrogen, and that is the trouble with bare wire—there is no control, nitrogen is always high on whatever electrodes you have. Well now, in automatic heat control, you have hydrogen gas going through and in going through the arc it is transferred to the automatic state and in the process it collects the heat from the arc and then gives off the heat that it has collected, in other words you get a hot spot on your material. By means of that process a very large number of metals that have been previously deemed to be unweldable are now welded successfully, but you require a special machine. It is a cumbersome business and it is used tremendously in the fabrication of different measuring intruments.

MR. FINLAY: I do not think the lecturer quite understood me on the machine tool weld and the automatic heat control. We have one firm in Sidney that, I believe presses out of sheet steel and for the slides they weld on only a bronze material where the rim of the trays lays down in the slides of the trays.

THE LECTURER: You can weld on two different materials but when you start doing that you want again to be careful of your electrodes. Another case something similar is, for instance, the welding of rails, but I have known firms to use similar electrodes and cracking took place alone the rail because it is a high carbon steel, and in this case the welded metal was of such a nature it became brittle and cracked,so that you would find that with certain materials you can do it quite nicely and others you cannot. No doubt if it was done in Australia it can be done, but I imagine it was a special thing. We use covered strips for straight-gap welding and you use special rods.

MR. MATHYS: I imagine sometimes after welding a frame together you have to machine it across the welded surface and I would like to know whether the machining of the welded surface presents any great difficulty, or is any more difficult than the actual frame, and also the sections shown on the screen are all equal sections I think, and sometimes you probably have a thin section welded to a thick section, are you going to encounter any difficulties there in cooling ? Do you have to control cooling at all ? I remember seeing once some motor-car wings welded to the body, and the method employed there was flash welding I think, they did not use any

electrode at all. Has that method been used in machine constrc-tion ? And the last question, we were shown different methods of construction. Is it possible to go a step further and use alloy steel. I think that is all I have to ask.

THE LECTURER : About the machining. When you are using mild steel the value of that is about 130 to 140, something like that. Ordinary mild steel electrodes are something higher than that but nothing to speak of. There is no difficulty about that at all, it varies from time to time ; you can get harder or softer deposits. If you want a special one you can get it, but normally there is no difficulty at all, your welded material is just slightly harder than your steel, but not enough to bother about. As regards different sections, no, there is no difficulty at all. There is nothing in it as difficult as there is in gas welding. The heat is very low and very concentrated, so that you affect only the part of the steel that is connected.

If you start at one point, and in this welding you find that it will expand in advance so that the relative expansion is different, and when you have finished welding the whole thing goes back and it bends, you can use what is known as "spot welding." You start at one point and you weld a bit at a time, so that when you are joining the middle another section retains its position. At first you are probably rather apt to get one or two difficulties in more ways than one. I do know, for instance, one firm where they were very advanced welders, but unfortunately they overlooked the difficulties about the factor of safety which they had on the slides and sliders of the rims, and the result was that the sliders just bent, so their welder thought along these lines, "Well, if it bends that way afterwards, I will bend it up this way first." It is the right idea. You get that by experiment—that is one of the ways you learn—but unfortunately the welder did not apply his brains, he looked at it, and being quite certain that you could not have the crossbars standing out he began to bend them the other way. Well, they never made that mistake again. They knew after that, and they just applied the right sections, and they are doing them to-day, with excellent results, and you cannot see the light between them. The same can be applied to any case where you might encounter difficulty. Then you mention about flush welding. That again is one of many methods of welding.

MR. MATHYS : If I remember rightly they did not use any electrode.

THE LECTURER : You have a special machine, you join the usual thin plates together—sometimes it is known as electrical riveting—you base your supply on a very low voltage and a very high amperage. It continues for a minute so that there is no supply, then you apply pressure at the right moment and you obtain a voltage well,

100% efficient. In many cases you have three variables; the time required, the amount of pressure, and current. All these vary for the job you have in hand, and as they are very difficult to determine the machine is automatic. All you have to do is to press a button. Now, 100% efficiency is claimed in the majority of cases. That type of work is generally light, and also it has its applications, and if you have a mass production job you can usually spot weld or butt weld, flash or oxyacetylene, and if you are always doing the same things I think it is well worth while to buy a reliable welding machine and do it that way. You cannot beat it for price because your workmanship is eliminated and you have nothing to pay for your electrodes, and the amount of current you use is very slight indeed. Only, for a job like that, if you vary the size at all, you have got to have a new machine or adjust the old one.

As regards alloyed steel, this is used quite frequently, but this is one subject it is not possible to talk about generally because you have got one thing to take into consideration, and that is the nature of the material itself. Now, cast iron is very much cheaper than mild steel, and if you have eliminated the casting of cast iron probably it would pay you to use more cast iron in your machine. Some people claim to open weld, and others want electrodes for it. No welding company in England will guarantee a cast-iron weld.

Now in alloyed steels you have roughly the same condition, it depends upon the elements, some are perfectly all right, others are not, and it is not enough to say, "Can you weld stainless steels?" for instance, there are a very large number of stainless steels and some are quite unweldable. The same applies to nickel steels, I think you probably know that, for again they are used quite a lot.

I was present at a lecture a little while ago, when the question whether it was possible to weld nickel steel was asked, and the answer given was that it is definitely weldable. Now that is an answer I would not have given, it is very dangerous. I have had some experience of that type of steel, and I have found that if your carbon is very low in that steel that amount of nickel is not a disadvantage, but having the same amount of nickel you will find that when you are carboning in base steel it becomes almost hardened, and I would shun it for welding, even with rod welding.

The best thing to do, if you want to weld nickel or alloyed steels, is to write to your nearest electrical manager, who has probably had some experience of it already, and if possible send him a sample, and if it is weldable he will give you an electrode. If not, he will tell you frankly that it is not. It will not be to his advantage to do anything else.

Mr. Durant: Now, a question regarding machine work. Is it not possible to heat the surface of an acetylene blow-pipe by using excessive acetylene, you can make a very nice job and increase

the hardness considerably, or alternatively use Stalloy, which will make a glass-hard surface. With regard to stress-relieving, we ourselves build compressors without any pre-heating or stress-relieving at all, simply by observing the correct procedure.

THE LECTURER: I quite agree with you about the oxy-acetylene; that is one of the disadvantages of oxy-acetylene welding to which I referred. You can have an intervening jet of nitrogen or oxygen, and if you have an oxidising flame then you are introducing oxide into your welded metal. An entirely oxygen flame is all right, an excessive acetylene introduces carbon, and that is the danger in welding if the operator is not careful. Now with regard to Stalloy, there is another preparation called "Stannate," I think, and I think they are supreme in their own particular application.

MR. DURANT: You could dip machine tools in it and use them on a flame.

THE LECTURER: I do not know about machine tools but it is used quite a lot with rock drills, but even there you will find that when you come to really hard ground you cannot drill with these tools.

With regard to stresses, I agree with you entirely, the stresses would remain there except where you have to machine or except where you have very severe conditions of work I would not have dreamed of stress-relieving.

MR. DURANT: I think stresses, particularly in machine work, are an advantage.

THE LECTURER: Yes, but I think they are inclined to disappear. I know many experiments have been carried out, and if you look for your stress after a period of time you will find that your internal stress has practically gone. I think you can do far too much stress-relieving, there has been less done within the last two or three years and it is definitely dying out.

MR. REEVE: I do quite a lot of framing in steel about 16 to 20 gauge and there are two questions that I would like to ask you, one is in connection with A.C. and D.C. machine work. Now at 16 and that thin gauge some manufacturers say that D.C. is the only machine that will do and others say an A.C., and also on some joints that we get on some electrodes that we are using lately we have had breakages after fabrication, and the breakages have occurred outside the weld. Is that due to the fact that the electrode we are using is of too hard a metal and stress has taken place in the sheet metal that we are using, causing the breakage? If so, can we get a softer metal as the basis of the electrode to obviate that trouble, or is it to do with the coating on it?

THE LECTURER: How thick were the plates that broke?

MR. REEVE: 16 gauge.

THE LECTURER: I see.

Mr. Reeve: Another point I wanted to mention about resistance welding was that on some of the jobs you get a blemish after a period on the bottom of the electrode. Now if you use an ordinary plate electrode about an inch square what is the effect of that?

The Lecturer: Well, when you start talking about 207 and so on above that, you ask me how I would weld. I should say oxy-acetylene, and I find it very much easier than with the arc, simply because in a very thin gauge like that the very thing which is a weakness, in oxy-acetylene for ordinary purposes, the fact that you operator can vary his heat, becomes the strength, because he can chip or blow away his slag from the weld, which might again damage the arc. So for very thin gauges now oxy-acetylene has it. As regards breakage, I do not think it has anything to do with the electrode, I do not see how it can. Very often faulty design will cause a break outside. I am wondering whether the bar material itself might even be at fault.

Mr. Reeve: Quite possibly, it is just ordinary black plate that the R.C.A. are using, and that particular breakage or fracture has only occurred when using that special type of electrode. However, the practice of fabricating to 18 gauge and 16 guage is quite a standard method with us and we have no trouble as a rule.

The Lecturer: That's all right, but I would not go above 18. Are you using 16 gauge or 14?

Mr. Reeve: Fourteen.

The Lecturer: Oh yes! I know it is done; I could even tell you of a firm that are using an 18 gauge for 200 amperes current, because they have to hold it at the top. They call that stud welding, it is not welded through. For their job it is all right.

Mr. Reeve: It is a question of the speed of operation; in other words you can delay the welding process.

The Lecturer: It can be done, but 16 is perfectly all right, and even 18, but when you come above 20 I think probably the other process is easier, but do not let me suggest you change if you are getting on with the job with the electric.

Mr. Reeve: And the question of the resistance on the electrode?

The Lecturer: Well, that is quite a point which has to be considered. You are talking about special welding. The welding is done by raising both the plates into position or applying pressure as in resistance welding, then another temperature correction takes place between the surfaces, now the pressure is applied by the electrodes themselves and you have got the heat. I believe a method has been tried out where the electrodes similarly carry the current, but I rather think the method was not found to be very satisfactory, because you do not get sufficient pressure actually on the statistical range and you do not get them grooved, and I understand

they cover over with putty on the top and then paint it over. The only time I object to putty is in structural work. I have had a query from one of my welders at the Bank of England as a matter of fact. He said that he had had fifty years experience and could weld almost anything, but there was one he could not make. When we came to examine it we found that evidently the job had been done in a hurry, and in that particular case I suppose someone thought he would fill it in with putty and paint it over, and naturally you could not weld that.

Mr. Robertson : There is one point I should like to have out and that is the preparation of the various materials going to make the various parts. I think the lecturers will agree with me that it is very vital as regards distortion and cracking to have standardised parts, and another point regarding that is the number of runs for the size of the weld ; that is a very important point I think, especially with regard to the first run—the root run—a very important run which wants doing with the correct size of electrode.

Another point is the bending or stressing of the fabricated part before actually trying any welding, by which to correct any distortion that may take place. I think that also wants stressing very much, because little can be done in that direction to overcome distortion. I noticed this particularly on the slide. I suggest that the only way to correct this is to place them after use on backing strips and clamp down, then they will not get distorted.

Regarding welding for vacuum type work and also automatic welding. What does the lecturer think of that side of the business, and again with regard to bare wire welding, I think that the lecturer is rather biased against it, but possibly he has been let down rather badly. However, I feel that several of those bed-plates on the various machine tools could be well welded with bare wire, and one other point regarding cast iron. Would you recomend the welding of cast iron ? Of course, I know the type of electrode is very important here, especially with regard to cutting. I know that anyone who controls welding, if he specifies a number of runs for a particular size of weld he is more likely to get the job he wants, although, of course, welders are very good fellows, but then I suppose they are interested in the money side, and of course it is much easier to remember one run generally than it is three.

Lastly, do you think welders are born and not made ?

The Lecturer : Well sir, I agree with what you have to say about preparation. I think a lot better welding can be done by having the plates properly prepared, especially when you have to plate them, but at the same time I am very much in favour of developing the type of material. In straight-gap welding if you turn it right out it saves a lot of cost.

As regards procedure, I quite agree that this is very important. If only the type and gauge of electrode can be specified it will save a lot of drawing office time. If that can be arranged and if the works can be induced to standardise their procedure so that the drawing office can at least be assured that if a certain weld is specified then there is nothing to be put on drawings and you can estimate anything in connection with the weld used.

As regards distortion, there are many ways, and one of the ways you mention is a very good idea and quite frequently used. Copper strip distortion generally can be overcome by welding procedure.

As regards automatic welding the difficulty usually is to get the current through your electrode, because if you have a corner wire the resistance varies as you use up more of it, and the machine becomes extremely complicated.

It seems as if you are getting away some of the protection, although I have seen one or two that are really good. The welds come out really magnificently, the only thing about is it that it costs about £3,000 to £4,000. You can save in costs by saving on labour if you can have one man looking after three machines then it probably would pay. Also, allowing for more or less standard conditions, if the machine is completely automatic then you eliminate the human element. However, I have seen some of those machines working, and very often instead of one man looking after three machines it is a case of three men looking after one machine. You do actually cut out the human element, and that is the one reason which I was given in that shop for the automatic welding. The machine does not de-slag it, the welder has to cut the slag out just the same, and then he leaves it at that.

A certain firm in this country has a lot of welding to do which is always the same ; the same length of run, the same material and everything else. They can do 37 ft. per hour welding on an automatic machine, and with a special type of electrode they can do 60 ft. per hour, but they have given up the machine and do it by hand, and I am not suprised. In that case there is no justification for a welding machine.

Then there was the question of bare wire welding. Two years ago we had a number of very heavy machines, completely welded of very thick plate. When I mention thick plates, the thicker the plates, the greater the tendency to crack, remember. Now a lot of the welding there was purely bare wire, and when they were welded 50% of them were found to be cracked, and the welder promptly got a pot of paint and painted the whole lot over. Well, that is what happens with bare wire, and I am all against bare wire, not because I have any experience, I never use it, but I think it is radically wrong to use it, the metal is very poor.

Then I think you mentioned the welding of cast iron. I am all for welding cast iron, and if it is a repair job it is always worth while to try and weld a thing before drawing it out. I know one case where someone came along to our school, and we usually try to work our courses as independently as possible, and I therefore asked him what he needed teaching, and he informed me that his father was paying up the money to put him into business, and in his district there were a number of foundries. He wanted to fabricate out of cast iron. I suggested that he might save his own time and his father's money if he changed his mind, and after showing him the different processes and so on he saw reason and agreed and left.

Well then, finally, about welders. I would not say that the welder is born and not made. There again, I have had quite a lot of experience of training men, we have had clerks, policemen, and bootmakers—we have had a few boiler-makers as well, but usually they learnt outside—and some of them, most of them actually if they persevere, can become a welder, but I do agree with you that there are people who simply cannot weld so that I suppose there is a justification for saying that if the majority of people are born welders there are a few exceptions. I cam across one case about five years ago. There was a fellow who looked the perfect welder. He started off and stood it for a day and there seemed to be nothing wrong, but on inspecting more closely I found that things were very wrong, for he insisted on shaping the arc not so much between the tip of his electrode and the plate as between his heels and our floor. Now it is difficult to believe it, nevertheless it is true, and of course it had a bad effect on his heels, as he pointed out. He insisted that I came round to see, and then he insisted on taking off his shoes and showed me. Well, in a case like that I would not advise anybody going in for welding.

Mr. W. Puckey (Section President, in the Chair): I wonder if the lecturer can give me any information at all on the welding of brass? Spot welding ordinary brass sheet has been done, and successfully in many jobs, but taking the same job again at a later date it would have been no earthly use spot welding then. As we have been successful in spot welding brass sheet can you give me any information on butt welding on brass?

The Lecturer: Butt welding? Well, butt welding really is not fit for brass, but I know that brass has been welded like that. You have your leads from your transformer and then you get a big resistance by tapping and that raises the heat. Now, in brass, copper, or anything like that the difference in resistance is very slight and therefore it becomes a lot more difficult to weld, that is the big trouble, and possibly there the least variation in your section or in the material would probably make a tremendous difference whereas

with materials of high resistance it would not. I do not know anything at all about it from personal experience. I suggest that you get into touch with British Insulated Cables, who specialise in this type of work, and they will give you complete information no doubt, or probably the people who made that machine would be in a position to supply the whole information you want about it.

Discussion, Yorkshire Section.

MR. R. J. MITCHELL: We have had a lecture to-night dealing with what may be described fairly as a new world. It is an amazing thing in engineering, how with our noses glued to the grindstone, we may be unaware what the fellow in the other street is doing. I think it is one of the great difficulties for the engineering profession in general to become aware of the vitally important movements which may be developing almost within ear-shot. Mr. Reisser has undoubtedly proved his case.

MR. J. D. SCAIFE: In this matter I regard myself as one of the re-actionaries. I cannot, somehow, bring myself to look upon machine tools, at any rate, as being made out of welded structures. I know that for some years my firm has been the opposite of friends of the foundry people. The number of cores and complicated structures we have been putting into machine tools of lately has rather put grey hairs on to the heads of the foundry people. I do not know what the welding people would think about us if we gave them the same sort of propositions. I think they would die an untimely death. The incorporation of slides—either chilled cast iron or hardened steel—appears to be a difficulty, especially in machine tools of a precision nature, and I am doubtful, having been brought up on close grained cast iron, whether this can be satisfactorily accomplished. I feel I shall remain on the " chilled cast iron " school to the end of my days. At the same time we have to live and learn, and we have had a very interesting and instructive lecture.

MR. REISSER: The slides would be incorporated in exactly the same way as hardened steel. You cannot weld these, but there are other ways of fixing them. I cannot quite agree about cast iron being superior, except in the case I mentioned at the beginning of my lecture.

MR. F. GROVER (Section President, in the Chair): Mr. Reisser made reference to the internal stress in cast frames. Can he tell us whether the expansion due to the welding heat does not produce similar stresses in the fabricated structure when cold ?

MR. REISSER: With respect to the annealing of the castings, you do the same thing in welding, if necessary. It is not always necessary, but if you are going to machine it afterwards, and if you are working to small clearances it is advisable to anneal. This is done in America quite often, and also in England. As regards expansion, the expansion of the whole job is negligible because the big difference between arc welding and oxy welding is that we have

a very intense but localised heat, and the expansion is small. It does not spread and you do not have much difficulty there.

As regards the pulleys and the Deisel rail car. Well, a certain amount of fitting is necessary, but here again it is very easily done in welding. You merely place the part in position and the welder touches it with the electrode and it is fixed for good. That is called tack welding. The speed of welding is very high indeed. For instance, a $\frac{1}{4}$ in. fillet, 1 ft., can be put down in about three minutes and that includes the work of the welder and the changing of the electrodes, so that speed of operation is very fast.

As regard the drawings and the acceptability of the work, it is one of the very great advantages of welding. All the work is done from one side only, so that we can use sections in welding work, which cannot be used in any other type of work on account of the connections, except, of course, in castings. The best example is ordinary steel structural work where you can use with welded work box sections of two channels welded toe to toe, and you can weld on the outside, whereas in riveting this connection is always difficult and frequently impossible to effect.

Another point is inspection. So long as you do your welding according to a definite procedure you can be quite sure that your welding is good, and you can judge it by visual inspection. The quality of the weld metal is independent of the operator. It does not mean to say that the operator cannot give you a bad weld, but what we do claim is that if he does you can judge it by visual inspection, provided, of course, that procedure was controlled, that a definite current was used. So that all the inspector has to do is to watch the ammeter and see that the welding is being done according to the prescribed procedure. While we are on the subject of inspection I would like to mention that this question does seem a little unfair on welding since it is asked just because welding is a new process : How can you tell a good casting, to say nothing of a good rivet ? I have worked on constructional jobs and I have seen rivets tapped by inspectors and the heads fly off. There is a job that I know of where one of the welders complained that he could not weld a cleat, so I had a look. That was a riveted job which had to be welded on site, and I was not very surprised he could not do it because in place of a packing there was putty. If you are going to demand non-destructive tests for welding, I think it should also apply to castings and so on.

A VISITOR : I would like Mr. Reisser to tell me, if he can, what will be the ultimate relation between a competent smith—a man who makes joints in the fire, and your welding. I think there is a very good reason for many people's prejudice. Speaking for myself, I am prepared to take things as I find them, and only a few weeks ago I was at a demonstration of the representative of a very large

firm and I can safely say that all the people who went there to get an opinion would be wrongly prejudiced for a very long time. In fact, it was a good job he did not throw the stuff on the floor, otherwise it would have broken. I would like to ask if you have considered the possibility of making a crankshaft by joining a number of small pieces together by electric welding as against the same job done by the smith. I think the person who may be affected very seriously is the blacksmith. My own opinion is that your electric welding is alright for very heavy work up to about 3 in., but take the case of, say, a crankshaft. I myself have had to go over a good many jobs, particularly light ones, done by electric welding, and it has made a satisfactory job. In fact, I have seen certain jobs, particularly small parts, made out of $^1/_{16}$th mild steel which have been stronger than those done electrically. I am prepared to admit that electric welding will develop, but I would like to know, in a general way, whether the blacksmith will be affected. I think these people will be affected in some way. I would like to know whether it will be more or less superceded, or whether electric welding and the smith will be complementary in their work or otherwise. So far, I take the view that the smith will hold the field for light work and that electric welding will be alright for your three-quarter mild steel for work of a semi-precision kind.

MR. REISSER: I do not think you are being very fair to welding, as you have taken an example where an expert blacksmith has made a 100% job. If you are going to consider an expert blacksmith you should consider an expert welder, and I have no hesitation in stating that he will hold his own against a blacksmith. For say you have seen a lot of welding which was very poor. I can quite believe it. There are quite a number of poor operators, but they would not be used for important work. I think it is just possible to get an unsound joint in the forge as it is by welding with the wrong procedure, and a poorly trained operator. I do not think a comparison between forge welding and arc welding is correct. Arc welding is taking the place more or less of castings where applicable. In forgeing you get a rather different case and I think that the forge is being replaced to a very large extent by resistance welding, because in the forge you use the same method of raising the temperature of the material to a point where it becomes plastic and by hammer blows you get crystallisation taking place, and with the right amount of blows you would get a 100% job. Now resistance welding is exactly the same except that instead of the forge to give you the heat, you have the electric current, and instead of the blows of the hammer you have the pressure which is supplied by the machine. In modern resistance welding machines all these variables are controlled extremely closely. The machine does the whole work and 100% efficiency is obtained.

With regard to connecting rods, that is a question I would not like to answer. It is a question of costs more than anything else. You should make a good job in welding, say, in mild steel.

A VISITOR: There is a certain arm in this country specialising in bronze and they are quite pressing what they can do with it. I know expert welders say it is good up to a point. These are the people who are making claims like this who are causing welding to be prejudiced.

MR. REISSER: I quite agree with you. One should not make more claims than one can justify. Bronze is a different kind of material entirely. Electric welding is good in certain cases for them. You are taking rather a special metal. You can take other materials and I would be the first to recommend a different process if you were going to weld them such as aluminium, which would require oxy-welding every time. On the whole, I think welding will compare with your blacksmith very favourably indeed, and in fact so long as you keep to a definite procedure you have very much more control over the quality of the work. I know there are some craftsmen who will give you a 100% job every time. but there are not so many of them, and in welding I think you may get even more uniformity then in forgeing.

A VISITOR: When you have three or four bed plates, is it going to be cheaper to make a pattern and cast them or have them welded ? Probably in the case of one it is cheaper to have a built-up fabricated body, but when it comes to three or four it would be cheaper to have a casting. I would like to know what quantity justified making a casting or how far you can go with welded parts. On the question of strength and design, is the comparative strength of a 1 in. plate bent at right angles to support plates at right angles welded with a fillet ?

MR. REISSER: The first question is one which is difficult to answer. It depends on the number, as you say, and also on the price of your patterns and whether the job is simple or complicated. In the case of the magnet which I showed you, It was definitely found that fabricating was very much cheaper, and as much as 120 tons a week are being fabricated which were previously entirely castings. It is merely a question of comparing the costs. In certain cases it definitely pays to fabricate by welding. In others it pays to get a casting, especially if it is a simple pattern.

With regard to the second question, that is, two plates at right angles, it depends how your welding is done. If you have two 1 in. plates and you have $^1/_{16}$ in. fillets they will break, but if you take two plates and you make them into a corner by filling the opening at the top and have a run inside because otherwise the thickness of the fillet would be less than that of the plate—then you can flatten them completely. The same with a T piece. You take two

⅜in. plates and put two fillets so that the combined throat thickness of the two fillets are equal to the plate, you will find you can bend your plate. You have to take account of the size and so long as you do that your welding is quite as good as your plate.

MR. A. SYKES: On the question of annealing and distortion, Mr. Reisser said that you have to anneal where necessary. I should like to have some guidance as to when it is necessary to anneal, and when it is not. We have had several cases where we have been a little doubtfull but I cannot say we have really had trouble as regards lack of annealing. On particular example was a rather complicated machine tool bed, and it was suspected that it distorted after it had been machined. As against that we have similar examples of distortion in cast iron beds and castings. We had another example. Some very large rings, 12 ft. diameter, 20 in. wide and 5 in. thick. We welded these with a double V joint from bent slabs and one of them, after welding, split nearly half way through, but did not split through the welded joint. It split through the original metal—5 in. thick—but the joint itself held solid. Our solution was to heat the joint with two long gas burners so as to get the temperature during welding on each side of the joint as near as possible uniform, and at the same time the welding was continued night and day until it was completed. The breakage in that case occured before we got it into the annealing furnace. Can Mr. Reisser give me any suggestions as to how we could have done any better than we did?

MR. S. M. REISSER: When I said annealing should be done when necessary, I had in mind the tolerance to which the work had to be done. When working to thous—it is advisable, but, for example, in structural work all distortion can be usually over come by procedure and annealing is quite unnecessary. I mentioned a good example of this latter case at a meeting of one of your other branches. It occurred at one of the railway works in this country during the fabrication of a sole bar for an undercarriage frame. The welding was too heavy in relation to the flange thickness and the flanges curve downwards. In this case, it was most important to have the flanges straight and horizontal and a solution was found by experience. The foreman decided that by bending the plates in the reverse direction prior to fabrication, the flange plates might be straightened by the welding—and this is actually one of the recognised ways of doing it. The first effort was a failure because the welder put it on upside down and it bent downwards worse than ever. But this proved the theory and —the amount of dishing having been determined by experiment—the trouble was eliminated for good.

As regards the second question, I should say the crack was to be almost expected and was most probably due to the use of incorrect procedure. Preheating is to be recommended in the welding of high

carbon steels and cast iron because—welding being a progressive operation—unequal contractional stresses are set up tending to produce cracks in the case of brittle materials. This tendency is reduced by preheating which has the effect of distributing these stresses more evenly and over a greater area of the base metal.

MR. A. SYKES,: With reference to the damping capacity of mild steel as compared with cast iron, it is recognised that internal damping of a cast iron structure is greater than that in a steel structure of similar proportion. With regard to welded gear cases, Mr. Reisser said that he had been informed there was no noise produced. We do find that separate parts of gear cases individually will give more ringing than iron castings, but gear cases are usually made up of two or three, or even more parts. As you strike one part you will get one sound, and another part another sound, and when they are joined together the sound is quite different, and there is a good deal of damping by being joined together. The same thing applies to wheels. If you take a solid fabricated steel wheel it will ring very intensely. If you get a wheel made in two halves the two halves bolted together will have a different sound from that produced by the separate halves—it is much more " dead " That is a question of the damping caused by minute frictional movements along the joint. We have found we could eliminate ringing to some extent in gear cases by making some of the parts from two thin plates spot welded together instead of one thick plate.

MR. GROVER: Mr. Reisser will go away with a feeling that that he has done a great deal of educational work, because the discussion has revealed that there are a good many sceptics present. Although the fabrication of machine frames may not always be convenient in the matter of accessibility for cleaning and repairs depending on design—yet one cannot regard electric welding otherwise than a great advance on the old blacksmith and forge method even though the forge has a survival value which is likely to persist.

Discussion, Eastern Counties Section.

Mr Anderson said with reference to the Bank of England job, he understood that this was designed entirely for riveting.

Mr. Reisser replied that this was so, but after consideration of the design, the Consulting Engineer decided to weld as this was cheaper. The bolts were put in the side sections to hold them for welding and were left in. However, the weld took the whole load.

Mr. Anderson asked if Mr. Reisser could give a comparison of the relative coast of welding as compared to riveting in an ordinary shop.

Mr. Reisser replied ghat he could do this if Mr. Anderson could tell him the cost of the riveting. He said that in normal structural work the welding cost would not be very high for welding.

Mr. Ayton referred to the previous question and said that there were a number of firms in this country who are experienced in welding and who could give a comparison between the cost of welding and riveting on any job ; his own firm has a large welding station and could give this information.

Mr. H. A. Webster asked if welding was more efficient with A.C. than D.C. current.

Mr. Reisser replied that D.C. is as good as A.C. and vice versa, providing the rod is made to work on both currents. D.C. is particularly efficient for very thin plate work.

Mr. Webster asked if a $\frac{3}{8}$ in. to $\frac{1}{2}$ in. section could be welded as well with D.C. as with A.C.

Mr. Reisser replied that this could be done, but against this certain electrodes must be used in the negative terminal. A.C. has not been such a snag as D.C.

Mr. Braid asked the lecturer if it was advisable to anneal after welding.

Mr. Reisser replied that a large number of firms do anneal after welding as distortion may take place during welding. You have to allow for this distortion while welding. He had not heard of many cases where distortion became evident after welding.

Mr. Newby said that his firm did a lot of welding which had to be put into anneal. He pointed out that in a certain welding frame which they built they started with a plate 8 ft. long, and that when the structure was finished it was $^{3}/_{16}$in. short. They did not, however, get distortion. There must have been some stress due to heat.